British Telecommunications Engineering

VOL 9 PART 4 JANUARY 1991

The Journal of
The Institution of British Telecommunications Engineers

British Telecommunications Engineering

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Published in April, July, October and January by *British Telecommunications Engineering Journal*, 2–12 Gresham Street, London, EC2V 7AG. (Formerly *The Post Office Electrical Engineers' Journal* Vols. 1–74: April 1908–January 1982.)

The Board of Editors is not responsible for any statements made nor the opinions expressed in any of the articles or correspondence in this *Journal*, unless any such statement is made specifically by the Board.

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Printed in Great Britain by Unwin Brothers Limited, The Gresham Press, Old Woking, Surrey, GU22 9LH.

Subscriptions and Back Numbers
Price: £2·50 (£3·00 including postage for UK; £4·00 including postage for overseas). Annual subscription (including postage and packaging): £12·00 (UK); £16·00 (overseas). Overseas customers can pay by sterling drafts drawn on London for £16·00.

Price to British Telecom and British Post Office staff: 90p per copy.

Back numbers can be supplied if available, price £2·50 (£3·00 including postage for UK; £4·00 including postage for overseas).

Orders, by post only, should be addressed to *British Telecommunications Engineering Journal* (Sales), 2–12 Gresham Street, London EC2V 7AG.

Remittances for all items (except binding) should be made payable to *'BTE Journal'* and should be crossed '& Co'.

Advertisements
All enquiries relating to advertisement space reservations should be addressed to The Advertisement Manager, *British Telecommunications Engineering Journal*, 2–12 Gresham Street, London EC2V 7AG. (Telephone: 071–356 8050.)

Communications
All communications should be addressed to the Editorial Office, *British Telecommunications Engineering Journal*, 2–12 Gresham Street, London EC2V 7AG. (Telephone: 071–356 8050.)

Binding
Readers can have their copies bound at a cost of £16·00, including return postage, by sending the complete set of parts, with a remittance to Pressbinders Ltd., 8 Newington Industrial Estate, Crampton Street, London SE17 3AZ.

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0262–401X/91 $2·00 + ·00

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British Telecommunications Engineering

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EDITORIAL

1991 promises to be an exciting year for the *Journal* as we have several interesting developments taking place. Last year, in a questionnaire, we asked a sample of readers and non-readers what they thought about the *Journal*. The replies were most interesting. The *Journal* gained high marks for being professional and authoritative, and many useful comments and suggestions were given.

As a result, the Board of Editors has reviewed the content of future editions, programmed a number of special editions, planned some changes to style, commissioned a new cover and approved a new supplement. Our objective will be to provide you with an up-to-date telecommunications journal which preserves the *Journal*'s long-standing high reputation.

A new publication, *Telecommunications Engineering—A Structured Information Programme*, to accompany the *Journal* is being launched in July 1991 (further details are given in the announcement on the inside back cover). This new publication will be authoritative, up-to-date and cover all aspects of telecommunications engineering—marketing, transmission, switching, finance, etc—over a 3 year period. This new publication is intended to meet the need indicated by replies to the questionnaire for information on current practices. It has been prepared with the support of BT's Telecommunications Engineering Staff College (see article on p. 260), and the Board of Editors is pleased to announce that Keith Ward has been appointed as Editor-in-Chief. At this stage, it is not intended to publish question-and-answer supplements as the demand for these has fallen.

Turning to this edition, you will find a wide range of articles. It is appropriate that several of them consider various aspects of service to customers. The article 'ServiceDesk—A Help Desk Support System' on p. 230 describes the contribution made by the help desk to support the strategic need of companies for information technology and network services. The article entitled 'Electronic Trading: The Development of Electronic Data Interchange Services for British Telecom' on p. 235 outlines BT's approach to meeting the electronic data interchange of its own 'trading community' and those of its major customers. Further articles describe the continuing developments of the digital network, fibre and other aspects involved in providing modern telecommunications services.

The 1990s will undoubtably be a period of considerable change and development. We believe that the developments detailed above will enhance the quality of the *Journal*. As always the critical test concerns you our customers; your comments are always welcome and valued.

C. R. J. SHURROCK
Chairman of the Board of Editors

ServiceDesk—A Help Desk Support System

T. R. K. ARNOLD, and S. L. HOLLOWAY†

Private networks are becoming larger and more important to companies' businesses. This is increasing the importance of a well-run and well-supported help desk to provide and maintain these networks. This article outlines the organisation and responsibilities of a typical help desk and describes the functions and facilities needed to support it. The article then describes the ServiceDesk product in terms of the facilities provided to address these needs.

INTRODUCTION

ServiceDesk is a system intended to support the people operating and managing a help desk. Help desks exist in a number of different environments; for example, they may support a voice/data network, or a company's computing operations. They share several common responsibilities and functions with which ServiceDesk provides assistance.

This article examines the common roles and responsibilities of a help desk, and how ServiceDesk addresses the problems.

BACKGROUND

ServiceDesk is a product in the BT portfolio; it has evolved from an earlier system known as *Linesman Fault and Resource Manager.* In addition to sales to various companies, ServiceDesk is used by the British Telecom ServiceCentres serving major customers, and by British Telecom International. ServiceDesk runs on VAX computers from Digital Equipment Company, and is based on a relational database.

HELP DESK RESPONSIBILITIES

A help desk is just one of several components of a support organisation: some are dealing directly with customers, while others have particular 'back office' responsibilities, which are often defined by technical, service, operational, or geographic boundaries. This is illustrated in Figure 1. There is often overlap between these logical divisions, and some help desks will combine several components of the support organisation into a single operational unit.

A help desk normally has responsibility for responding to questions and reports of problems from users of a service or group of services. Often, it is also responsible for providing service to new users. The users can be viewed as the customers of the help desk. The help desk often relies on other companies or organisations (known as *agents*) to complete the process. Since the help desk represents the contact point with the customer, it usually has overall responsibility for each job, and acts as the customer's 'champion'.

Although the nature of the services used may vary from one help desk to another, there are general responsibilities and roles which are common to most environments:

- customers report problems, which must be recorded and analysed;
- the help desk needs to pass problems to the responsible agents;
- customers must be informed of progress;
- the resolution of all problems must be monitored and managed;
- service levels, such as time to clear a problem or time to respond, must be met;
- changes to the service or its users, such as adding a new user or modifying a network configuration, must be controlled; and
- the help desk needs to make the best use of available resources.

In general, the workload of a help desk consists of a large number of relatively small tasks, each of which needs to be progressed separately. Further, since a help desk is primarily a responsive organisation, the workload may vary considerably from hour to hour or day to day. The amount of resources available to the help desk, either directly or indirectly, is normally limited, and it is important to be able to prioritise tasks and meet agreed service levels (such as problem clearance times) despite varying workloads.

BASIC FACILITIES REQUIRED

In order to perform these tasks, the help desk needs certain facilities. There must be an accur-

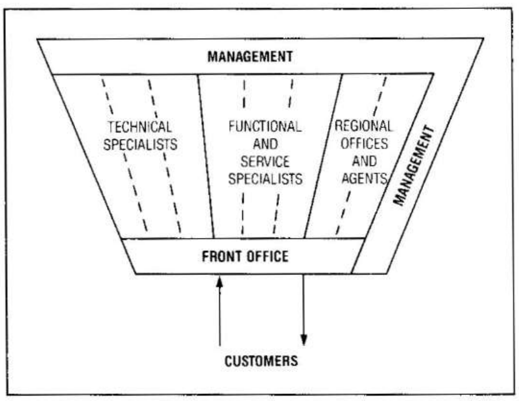

Figure 1
Typical help desk organisation

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† Customer Systems, British Telecom Communications Systems Division

ate record of all of the customers and equipment or services to be supported. This is essential to the validation of problem reports, and the control of changes to the services being supported. Where specific maintenance contracts or service level agreements are used, this information also needs to be recorded, so that commitments can be met (such as response time).

A record must also be kept of the progress and result of each problem report or change. This permits each task to be tracked, and provides a record for later trend analysis or subsequent investigation if necessary.

However, as the volume of work for help desks has grown, and the dependence of customers on the services (particularly network and computer-based services) has increased, the information requirements of help desks have increased also.

ADDITIONAL REQUIREMENTS

As the dependence of customers upon network and computer-based services has grown, the importance to the customers of speedy and reliable provision and maintenance of service has increased. Simultaneously, help desks have been coping with an increased workload and pressure on the available manpower as its relative cost increases. This has raised the need for systems to prioritise work and to assist with its timely completion, for both provision of service and repair.

To maximise the use of scarce skilled resources, help desks have increasingly introduced specialisms, such as particular technical skills or customer and telephone skills. This means that a number of people will be involved at different stages of each job, which needs to be tracked at all stages. The managers of help desks need more information in order to be able to allocate resources appropriately and to detect and correct problems before they cause contracted dates for provision or times for fault clearance to be passed. Longer-term information is required in order to monitor the help desk's performance against objectives, to monitor equipment and service reliability, and for planning future resourcing.

Whereas in the past help desks were able to rely on paper records to provide the basic facilities, the additional requirements and workload cannot be met in this way. Within BT, the Strategic Systems Plan addresses the requirements for help-desk-type systems to support BT's own production systems. ServiceDesk fits these requirements well.

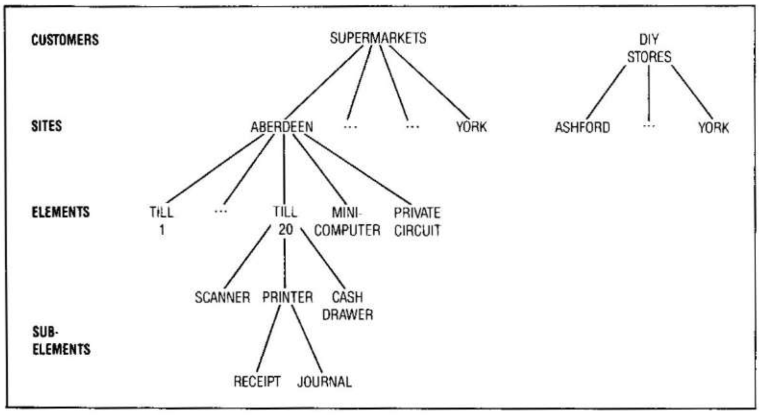


Figure 2
Example inventory structure

SERVICEDESK FEATURES

Inventory

ServiceDesk maintains an inventory of the equipment and services which are supported. This is presented in a hierarchical form, as illustrated in Figure 2, showing a part of the inventory for the help desk of an imaginary retail company. At the top layer (known as the *customer layer*), details are kept of the main networks or services or customers supported through the help desk. In the example, there are two main divisions, supermarkets and do-it-yourself stores. The next level of breakdown is to individual sites. Each site will have a certain amount of information recorded, such as contact information for the site and for the agent responsible for supporting the site (such as the regional office).

The lower layers are known as *elements*. Beneath each site are recorded details of all the equipment or services supported through the help desk. In the example, the Aberdeen supermarket has 20 tills, a small computer for controlling the tills, and a private circuit linking it to the head office mainframe computer. Elements may be decomposed (up to three more levels), in order to record their components. In this case, Till 20 is shown as consisting of a bar-code scanner, printer and cash drawer. The printer has two further subcomponents which are concerned with printing the customer's receipts and the till's own journal.

Information recorded about elements and sub-elements may include a description, location, details of the manufacturer, supplier and owner (in the case of leased or rented equipment), the equipment type and category (for example, for statistical analysis of reliability of different sorts of equipment), and contact information for the agent or company responsible for repairing it. The 'class of service' is also recorded, which identifies the time-scales and stages required for fault-fixing. This is described more fully below.

Thus, the inventory allows those operating the help desk to know what they are responsible for maintaining, where it is, whom to contact, and what sort of maintenance agreement applies to each item. This is the basis for the enquiry processing functions.

Enquiry Processing

The main task of the help desk is to respond to requests and reports from its customers. ServiceDesk provides facilities to handle orders and fault reports, using a common set of functions known as *enquiry processing*.

Each enquiry begins with the customer. Most contact with the customer will be by telephone, but some may be by letter or fax, especially in the case of orders or requests for change to facilities. A ServiceDesk user completes an *attention record*, entering information about the customer, the item concerned, and the nature of the enquiry or problem. In the case of a fault report, the enquiry is recorded against the inventory, so the attention record contains the customer, site and element. When this is entered, ServiceDesk displays information about any recent or outstanding problems on the item concerned. It also displays the class of service and calculates the date and time by which the fault should be fixed according to the maintenance agreement.

The next task is to progress the clearance of the problem. This is done by means of a *progress record*, to which the attention record is associated. Where an incident causes a number of fault reports (such as a failure in a piece of common equipment), several attention records may be created as the individual problems are reported. However, there will be a single progress record to record the work done to resolve the problem.

As mentioned before, a help desk may be divided into a number of different areas of responsibility. ServiceDesk supports this by the concept of *duties*. Each duty represents a role, and every ServiceDesk user will perform one or more duties. Several people may cover the same duty, thus forming a team. Progress records are allocated to duties, and may be reallocated as work proceeds.

People may record progress and other information on the job as *events* on the progress record. Hence a picture of the history and status of the job may be obtained at any time.

Once the job is complete (the fault has been fixed or the order fulfilled), the progress record is closed. This automatically closes all attention records associated with it.

ServiceDesk allows information to be captured during the progress of each enquiry, and when it is completed. This can be analysed for common activities, problems, and other management information.

Prompting System

The facilities described so far are passive: they simply record information about the inventory and about every order or fault being handled. However, in order to be able to ensure the timely completion of every task, ServiceDesk provides a comprehensive and flexible system of prompting. The prompting system is linked to the progress record and to the equipment to be repaired or supplied.

The basis of the prompting system is the *escalation profile*. This can be likened to a timetable: it breaks down a job into a number of stages, and defines times at which messages are issued if a particular stage is not completed. When a progress record is created, the relevant escalation profile is selected (determined by the class of service), and the stages of the work and the times of the messages are calculated. As the help desk staff work on the problem, they complete the stages of the work. This information is recorded as events on the progress record. If a particular stage is not completed on time, the messages in the escalation profile are delivered. These may be classified as reminders or escalations. Typically, reminders are sent first, and escalations are sent subsequently if the stage is still not completed. This alerts a manager to a problem, perhaps caused by a high workload, or perhaps a problem with an outside agent who is late performing a task.

The ServiceDesk system manager can create escalation profiles according to the nature of the different jobs performed by the help desk. The system manager loads details of the time-scales, working days and hours, and job stages, as well as the times of each reminder or escalation message. Time-scales are entered in relative time; that is to say the number of days, hours and minutes after the enquiry was entered. When the progress record is created, ServiceDesk takes the relative times in the escalation profile, and calculates the actual times at which the messages will be sent. These may be displayed on the terminal.

This mechanism gives a means of breaking each job into stages, and ensuring the timely completion of each stage, with managers being alerted to problems before they cause contractual commitments to be missed. Thus each job can be controlled.

A further development of this allows the management of the workload as a whole. ServiceDesk facilities allow help desk staff to look at the progress records outstanding in various ways, such as all those allocated to a particular duty. ServiceDesk also provides a display of the prompt messages due to be delivered in a particular time period. This permits the help desk staff to anticipate messages, and become more proactive. A further facility allows the system manager to select a filtering level to control the workload. In times of excessive work, such as after a natural disaster, there may be a very high level of faults being processed. Each message has an associated priority, and the system manager can instruct ServiceDesk not to deliver messages of lesser importance.

Orders

The examples above referred in the main to how ServiceDesk tracks work on fault reports. The way in which orders are tracked is very similar, but there are a few essential differences.

The attention record for an order does not refer to an element in the inventory, but to a product. The product is validated against ServiceDesk's product master list, which also contains information on the escalation profile to be used. Different products may have different lead times, and require different stages of work in order to provide them; this is supported by using different escalation profiles.

When the attention record for an order is being created, ServiceDesk automatically calculates the normal delivery date for the order, based upon the lead time for the product contained in the escalation profile. The customer may request a different date, (either earlier or later than the normal delivery date); the date agreed is also entered on the attention record. Since the escalation profile will have been written for the normal delivery date, ServiceDesk expands or compresses the time-scales for the prompt messages to fit the new lead time. When an order is taken, additional information is often required beyond the product being ordered, the customer, and the site where it is to be installed; this additional information can be entered and is linked to the attention record.

The subsequent processing of the order (using a progress record) is almost identical to the progressing of a fault report, except that the stages and time-scales are normally different.

The facilities for handling orders apply equally well to other forms of enquiry, such as configuration change control or removal of facilities.

ServiceDesk Networks

It is relatively common for large companies or organisations to have a number of help desks. These can have different geographical or functional areas of responsibilty. It is very often necessary for these help desks to pass enquiries and information between them in order to complete an order or resolve a problem. Help desks which rely on paper systems, or on individual 'island' computer systems, often have difficulty with losing sight of a job once it has been passed to another help desk. They are often unable to keep the customer abreast of progress on the job, and co-ordination of the help desks is very difficult.

ServiceDesk systems may be linked in a network. An enquiry may be logged on one ServiceDesk, and subsequently passed to another to carry out part of the work. The original ServiceDesk system is known as the *owner* of the enquiry, and the second (and any subsequent) ServiceDesk is known as the *partner.*

When the owner decides to send the enquiry to the partner, the attention record and progress record information are copied to the partner. Subsequently, any information entered (in the form of events) by either help desk is copied automatically to the other system. This ensures that both help desks are fully aware of the progress of the work. Only the owning help desk is allowed finally to close the progress record, but once the partner help desk has finished its work, it can hand back to the owner; if the owner is not satisfied that the work is complete, it can reject the handback.

Inventory information is also distributed between ServiceDesks; the owning ServiceDesk enters the list of partners for each item in the inventory, and ServiceDesk automatically sends the information to the appropriate systems. This allows each ServiceDesk to hold all of the information it needs about the equipment and services for which it is geographically or functionally responsible.

Although on each item there is a concept of owner and partner, a ServiceDesk network can be treated as a peer-to-peer network, since each ServiceDesk may act as the owner for some customers, and as a partner for some inventory belonging to other customers. This gives each customer a single help desk as a point of contact, but allows flexibility in the help desk organisation to reflect functional or geographical divisions.

Other Facilities

ServiceDesk allows the system manager to define each user's ability to access the various features, and the duties which they can perform. ServiceDesk is a largely data-driven system, and allows a high degree of control over the 'support data' for the various facilities. For instance, the system manager can define the list of valid equipment types, the products and services, escalation profiles, the optional activity codes, and so on.

Several standard reports are provided by ServiceDesk. These cover the inventory (for example, showing the breakdown of the inventory belonging to a particular customer or at a particular site) and enquiries. A statistical report can be produced showing the success or failure rate of meeting agreed maintenance and provision commitments and, if required, giving a breakdown of any progress records which have been escalated.

Access to the ServiceDesk database is possible from other tools and from fourth-generation languages, so help desks can obtain customised reports and link them with other facilities. For instance, it is possible to extract information from the ServiceDesk database and load it into a spreadsheet, or incorporate it as text or a graph in a report.

OPEN INTERFACE

In addition to access to the ServiceDesk database by office automation tools, an interface has been developed which will permit the transfer of information in and out of ServiceDesk using an open network management interface. The interface is part of Concert^{TM}, which is a BT programme for open network management interfaces in its products and services, and for network management products based upon these interfaces. A Concert^{TM} interface has been written for ServiceDesk and for the BT ServiceCentres (which also use ServiceDesk software).

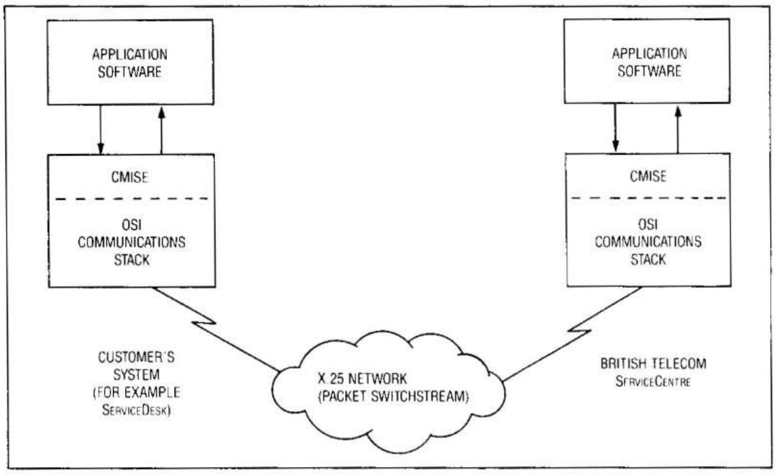
Initially, the interface permits fault reports to be passed between systems; for example, from a customer's ServiceDesk to the BT ServiceCentre which is responsible to the particular customer. It also allows progress information, in the form of events, to be passed between the systems, and for final closure information to be passed.

The interface is based upon Open Systems Interconnection (OSI) protocols, and follows recommendations of the OSI/Network Management Forum, an international body with over 100 members, including most major computer manufacturers, network operators, and network equipment manufacturers. The communications stack follows the OSI seven-layer model, using the common management information protocol (CMIP) as the upper layer protocol. (Figure 3.)

Conversations between systems take place about instances of the attention record managed object; each fault report is represented by an instance of the object. This has a number of attributes, such as the status of the fault and the identifier of the faulty equipment. Conversations between systems consist of requests and/or indications relating to the values of the attributes. For instance, when a ServiceCentre closes a problem, the ServiceDesk receives an indication that the status is CLOSED along with some textual information entered by the ServiceCentre user. The definition of the sort of requests and indications which may be made about an instance of the attention record managed object are known as the *object behaviour.* Figure 4 shows a typical dialogue about a fault between a customer's ServiceDesk and a BT ServiceCentre.

Any system which implements these protocols and supports the attention record managed object and its behaviour will be compatible with ServiceDesk and with the BT ServiceCentres. An open interface provides a significant advantage to BT and its customers over other systems which have proprietary interfaces or which only interface to other systems within a particular operating system.

It is intended to enhance the interface in the future to support the exchange of information about orders, and to augment the amount of progress information which is passed.


APPLICATION SOFTWARE
CMISE
OSI COMMUNICATIONS STACK
CUSTOMER'S SYSTEM (FOR EXAMPLE SERVICEDESK)
X.25 NETWORK (PACKET SWITCHSTREAM)
APPLICATION SOFTWARE
CMISE
OSI COMMUNICATIONS STACK
BRITISH TELECOM SERVICECENTRE

CMISE: Common management information service element

Figure 3—Communications between ServiceDesk and ServiceCentre

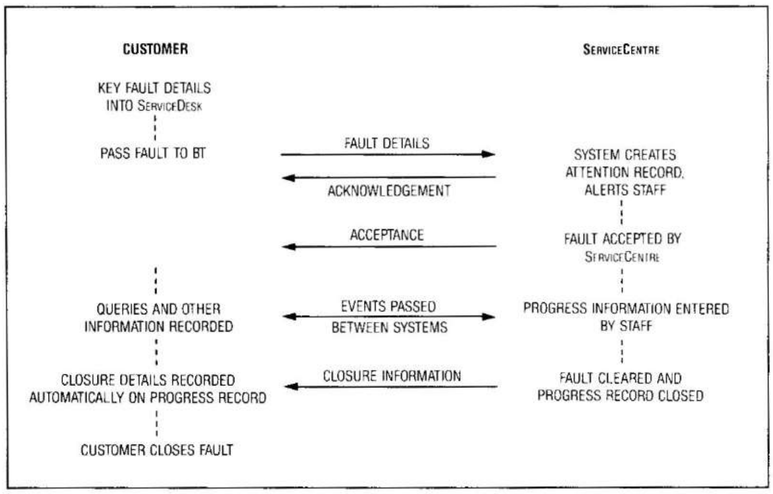

CUSTOMER
SERVICECENTRE
KEY FAULT DETAILS INTO SERVICEDESK
PASS FAULT TO BT
FAULT DETAILS
SYSTEM CREATES ATTENTION RECORD, ALERTS STAFF
ACKNOWLEDGEMENT
ACCEPTANCE
FAULT ACCEPTED BY SERVICECENTRE
QUERIES AND OTHER INFORMATION RECORDED
EVENTS PASSED BETWEEN SYSTEMS
PROGRESS INFORMATION ENTERED BY STAFF
CLOSURE DETAILS RECORDED AUTOMATICALLY ON PROGRESS RECORD
CLOSURE INFORMATION
FAULT CLEARED AND PROGRESS RECORD CLOSED
CUSTOMER CLOSES FAULT

Figure 4 Typical dialogue between a customer and a ServiceCentre using the Concert interface

CONCLUSION

As the dependency of companies on strategic information technology and network systems continues to grow, so the organisations which support them are facing increased requirements for reliability, responsiveness to problems and timely delivery of new or changed facilities. At the same time, there is increased emphasis on making the maximum use of human and equipment resources to reduce costs. It is essential that help desks are able to manage their work, and to progress each task to a successful conclusion. The ability to pass work around to the team or agent responsible for each stage is required without losing sight of progress. ServiceDesk provides a large number of such facilities, built upon an earlier product and operational experience in BT ServiceCentres. An open interface provides additional value in terms of allowing customers to communicate electronically with BT, and in terms of compatibility with other applications on other systems.

Biographies

Tim Arnold joined the company as a Post Office Student in 1977 and graduated in 1981 with a B.A. in Computer Science from St. John's College, Cambridge. His first job was as an Executive Engineer in Research and Technology division studying software development methods and software engineering training. In 1984, he joined a new unit in National Networks, and worked on a number of communication software and network management projects, including consultancy on the management of a proposed new private electronic funds transfer network. In 1987, he became project manager responsible for the development and support of ServiceDesk.

Steve Holloway joined the company in 1972 after obtaining a B.Sc. in Physics and an M.Sc. in Communication Engineering at Manchester University. His career has spanned several large computing and software development projects in public switching and network management. He also assisted in the establishment of the BT system software engineering centres. He now manages a section developing and supporting the national network traffic management system and ServiceDesk.

Electronic Trading: The Development of Electronic Data Interchange Services for British Telecom

D. J. BRUNNEN†

Electronic data interchange (EDI) has emerged from a long gestation period to be a key tool for the management of British Telecom and a significant trigger for the growth of managed data networks with design implications for a broad range of telecommunications services. EDI message switching facilities and applications are described together with an assessment of the project management skills that are key to effective implementation. The article outlines BT's approach to meeting the EDI needs of its own 'trading community' and those of its major customers around the world.

INTRODUCTION

Electronic data interchange (EDI) is formally defined as: 'the computer-to-computer exchange of structured business data in agreed (public) standard format.'

From a technologist's viewpoint, the challenge is to devise business systems that enable organisations to overcome the problems of disparate computer systems, communications standards, message formats and time zones (Figure 1).

From a business management viewpoint, the challenge is to deploy EDI in close collaboration with other organisations to realise large-scale cost savings and enhance the competitiveness of products and services.

From the viewpoint of the ordinary consumer, the hope for reductions in real costs (and improvements in choice and quality) of goods and services is offset by fears of unemployment and unease about the social implications of data interchange between different (but increasingly interdependent) computing systems.

It has taken about 21 years to progress from the earliest specification of EDI syntax and message standards towards large-scale realisation of consumer benefits. The effective application of EDI has 'grown up', driven by the enthusiasm and vision of technologists and tempered by the concerns of commercial customers. As a measure of maturity, it was significant that, at the UK's recent major EDI conference—EDI 90—British Telecom's principle contribution was not a technical paper concerned with communications protocols or message design details. The paper was given by BT's Group Treasurer and indicated the extent to which EDI is now being applied in business practice and is central to delivery of competitive telecommunications services[1].

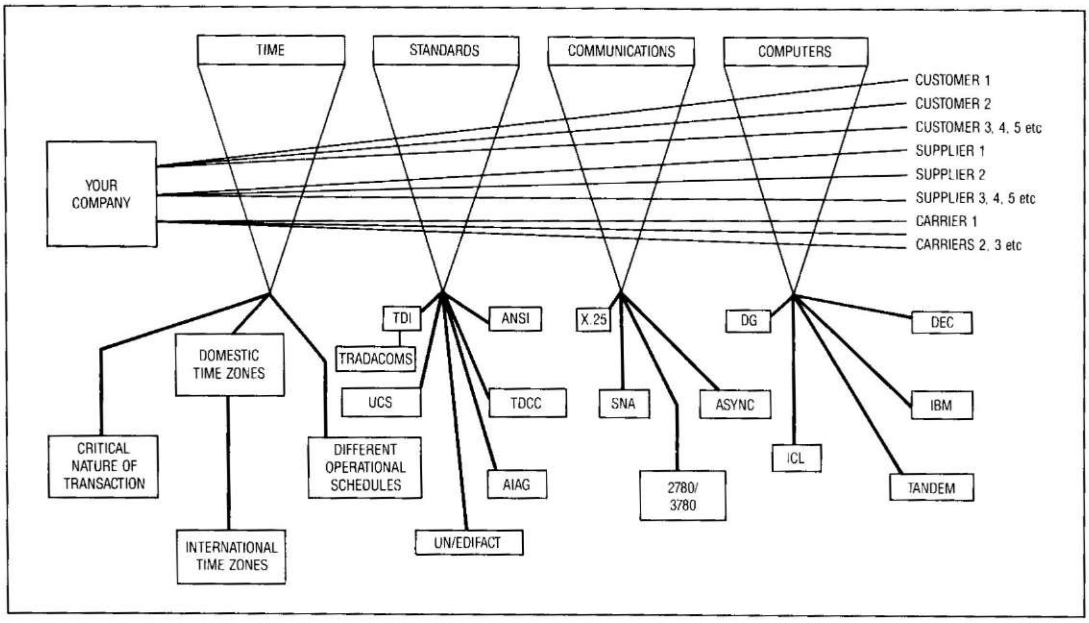


Figure 1
Point-to-point data communications

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† Managed Networked Services, British Telecom

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MESSAGE AND COMMUNICATIONS STANDARDS

As evident throughout the information technology (IT) sectors, large-scale commercial support and international standards are concomitant. The early work on EDI standards specification was rooted in two initiatives: the United Nations' Trade Development committee targeted at the simplification of international trading procedures and the US Defense Department's support for the Transportation Data Coordinating Committee (TDCC). (Appendix 1.)

The emergence of the UN/EDIFACT Syntax (1987) and its approval by the International Standards Organisation (ISO) as DIN 9735 followed a period where several competing standards for specific trading and national communities have been developed and, in some countries, gained significant local support.

This creative phase is now reaching maturity with a fairly stable infrastructure of standards committees and relatively clear programmes for definition of new message types. It is to be hoped that further migration towards the UN/EDIFACT standards will be achieved in the next 2 – 3 years.

A typical interchange format is given in Figure 2. The function of EDI software is to convert business application data from any system, such as purchasing orders or invoices, into an 'electronic' format for transmission, and vice versa upon receipt. The message syntax is a series of segmented code strings that describe specific fields (for example, for *item* or *quantity* or *unit price*) interspersed with the actual values.

A typical software package combines the central construction and translation of interchange data and the EDI syntax rules with linkages to the user's application software (for origination or receipt of data) and a file transfer protocol (FTP) associated with the communications process.

A major part of the design is concerned with the integrity of the electronic document and the use of error-correction transmission techniques. Many organisations gain their first experience of EDI by using this software on personal computers interspersed between the telecommunications network and major data processing systems. Immediate and costly redesign of output data files can often be avoided, particularly during a transitional phase when only a few trading partners are able to use EDI. In the longer term, system design engineers can provide more efficient and cost-effective solutions, but these are, in part, dependent on success in obtaining full collaboration within the relevant trading community.

A typical 3 minute on-line session between an EDI user's system and a networked EDI message switching service may consist of several hundred messages of varying types being routed to a large number of eventual recipients. These communication sessions are designed for operation without manual intervention and are typically triggered at routine time intervals to coincide with schedules of application systems which use their input or output.

```
– INTERCHANGE HEADER
      – FUNCTIONAL GROUP HEADER
            – MESSAGE HEADER
                  DATA SEGMENTS
            – MESSAGE TRAILER
            ::
            – MESSAGE HEADER
            |     DATA SEGMENTS
            – MESSAGE TRAILER
      – FUNCTIONAL GROUP TRAILER
– INTERCHANGE TRAILER
```

Figure 2
EDIFACT interchange syntax

EDI MESSAGE SWITCHING SYSTEMS

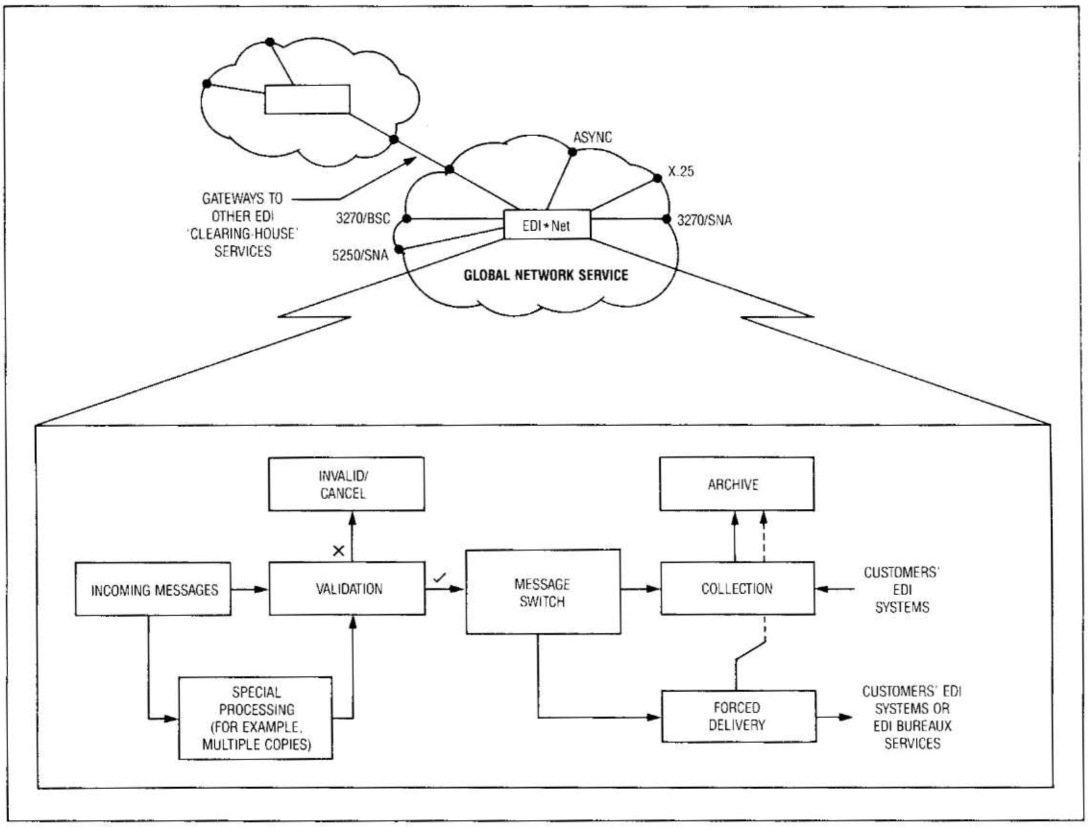
As in other areas of text messaging, the development of networked message routing services has emerged to overcome the inherent inflexibility of point-to-point communications. EDI*Net, developed in the USA by BT-Tymnet (formerly owned by McDonnell Douglas), is a typical EDI store-and-forward service. The design reflects a balance between centralised switching functionality and devolution of transmission controls to the supporting network and customer systems.

Figure 3 describes the EDI*Net system installed at Baynard House, London, which has supported the trial services since March 1990. The only significant differences to its North American counterpart are the X.25 connection to the UK's Packet SwitchStream (PSS) network and (during the initial trial phase only) a lack of 'outdial' links for the transmission of traffic to other EDI clearing house services.

Connection and log-on to the service are achieved with a minimum of interactive dialogue and EDI data are submitted for sorting, distribution and validation. The addressee on the 'envelope' of the data is checked against files of registered customers, the contents of the envelope are verified as containing the indicated number of documents, and the structure of each document is checked for conformance to the selected EDI standard.

EDI data moves through the clearing house in a series of queues. Incoming messages are directed by the system to either the *special process* queue (if the message requires a prevalidation special process) or directly to the *raw message* queue. After *special processing* processing, the interchange is then validated. Failures are routed to the *invalid* queue where they are monitored by support staff and (subject to authorisation) corrected and re-submitted. Major failures are routed to the *cancel* queue with advice to the originating customer to retransmit. The interchange data is routed to the

Figure 3
EDI*Net overview



relevant *delivery* queue for collection or onward despatch. After collection by the user, the data is directed to the *completion* queue where it remains for seven days before moving on to the *archive* queue. Finally, the archive queue is drained by a process that retains the data on magnetic tape for a further 60 days.

In 1988, Tymnet chose to upgrade its EDI*Net service from a mature IBM system to a large-volume transaction processing facility based on TANDEM computers. These systems are already well established within packet-switching networks and are popular with banks and financial services for their inbuilt 'non-stop' integrity and high-volume throughput. Typical service standards assume a maximum message delivery delay of no more than 5 minutes during peak traffic loads.

The network and message switching systems are supported by a team of customer and systems support specialists. This team takes a proactive role in the resolution of customer difficulties and is often able to identify and (within the freedom of service level agreements) take corrective action before the customer is aware of any problem. This support service is particularly relevant during initial testing and training where new customers have a wide choice of approved EDI software.

The EDI*Net service interconnects with all major competing services in the USA, and the X.400 standards for message handling systems[2] are expected to increase interconnectivity of network providers. It may, however, be several years before the more-established electronic trading communities who chose early entry into EDI (for example the users of TRADACOMS in the UK) are able to migrate to an international capability based on the UN/EDIFACT message formats. BT's contribution to EDI standards development has been bolstered by the acquisition of Tymnet and direct participation in both the North American EDIFACT Board's Technical Assessment Committee and the Western European EDIFACT Board (WEEB).

CUSTOMER IMPLEMENTATION

The logistics of EDI application between consenting companies has proven to be even more complex and challenging than the definition of EDI standards. The early history of EDI application in key industries such as motor manufacturing tended to highlight the changing relationship between major companies and their many smaller suppliers.

As an example, 'just-in-time' (inventory) ordering systems require that stock is delivered from the supplier to the manufacturing plants with as little as 4 hours notice. The implications for cash-flow and inventory logistics for smaller companies are one side of a complex realignment of trading practices that are motivated by identifying worthwhile benefits for both trading partners.

Considerable cost savings can be achieved if, for example, the trading partners can agree on evaluated receipt settlement (ERS) where payment is remitted to the supplier upon receipt of goods and their preceding EDI advance shipping notice. In ERS, the receiving computer reconciles the order received and automatically triggers a payment order to the banking system. Many businesses have targeted 'invoices' for priority conversion to EDI but, under ERS practice, these invoices (and their associated invoicing departments) are no longer required. ERS in turn, however, requires adaptation of financial auditing practices which may be subject to wider professional or legislative constraints.

With these complex application logistics, the development of EDI systems cannot be considered separately from their associated customer EDI implementation plans. The successful application of EDI within a trading community is dependent on a collaborative effort that is often seen by the major partner as a strategic investment.

A full range of programme management techniques has been developed by telecommunications companies for the management of large-scale network and switching installation projects and can be adapted to the large or small EDI implementation needs of trading partners. The EDI implementation process must also be adjusted to allow for variable levels of data-processing and communications-systems expertise found among trading partners many of whom have not previously been exposed to high levels of quality control for project management, systems design, testing, training and network services support.

EDI EXPERIENCE WITHIN BRITISH TELECOM

The EDI needs of BT range from relatively simple applications among parts of its organisation (for example, the inter-business charging system) through to complex collaboration with multiple suppliers and major customers. A typically large project concerns the supply of motor vehicle parts to garages servicing the company's UK engineering fleet. The manufacturer, associated main dealers and the service points (in total 275 interacting nodes) must all subscribe to a common plan and schedule for conversion of their trading practices and the installation of systems together with initial and ongoing training and support programmes.

This type of project must be sustained throughout by certain knowledge that the resultant benefits for all parties will justify the effort and investment.

The early work on the application of EDI within BT has benefited from the market experience acquired with BT-Tymnet. Figure 4 shows the organisational positioning of the EDI Active Support unit (box 8)—a relatively small group of specialists formed to identify and pursue a corporate policy of determined EDI application. This group has provided the focus for the multi-disciplinary effort behind the introduction of a European replication of the North American EDI*Net service and the definition of customer training and support programmes. It is intended that, as the implementation processes within BT are standardised and devolved to operational groups, the Active Support unit will migrate towards (Figure 4, box 4) a marketing and customer service capability to assist the company's major customers in the wider application of customised EDI services for specific sectors and communities. These services will be provided on a fully managed but *wholesale service* basis via *intermediaries* and embedded within the global network services. These intermediaries (Figure 4, box 6) are BT's major partners and customers who have significantly large trading communities and may also add elements of trading functionality (for example, banking services) to the basic message switching and network services.

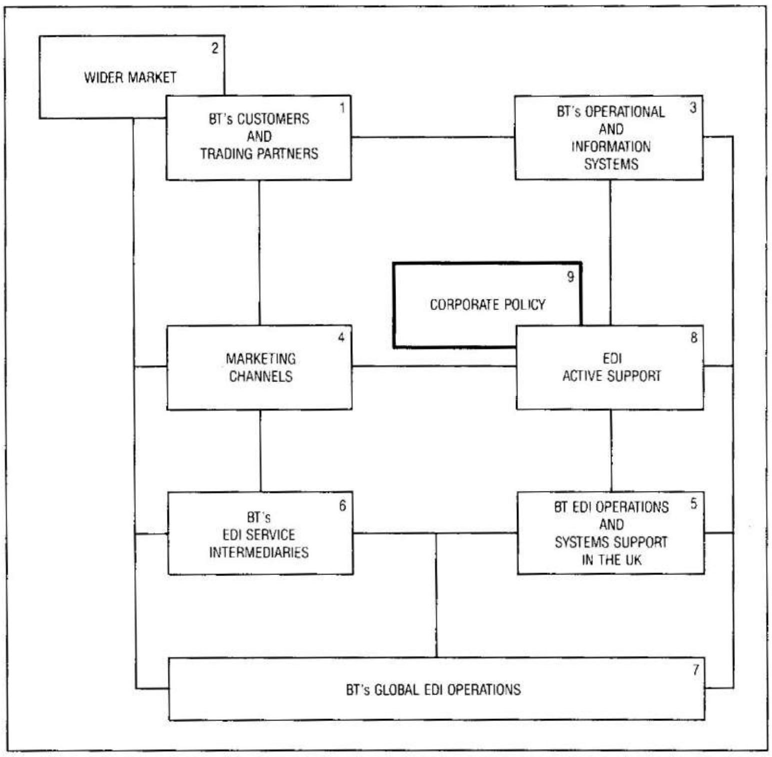

WIDER MARKET 2
BT's CUSTOMERS AND TRADING PARTNERS 1
BT's OPERATIONAL AND INFORMATION SYSTEMS 3
CORPORATE POLICY 9
MARKETING CHANNELS 4
EDI ACTIVE SUPPORT 8
BT's EDI SERVICE INTERMEDIARIES 6
BT EDI OPERATIONS AND SYSTEMS SUPPORT IN THE UK 5
BT's GLOBAL EDI OPERATIONS 7

Figure 4
EDI services within BT

THE WAY FORWARD

An additional plank of EDI development activity is not detailed in Figure 4 but is implicitly included within box 3. In addition to the logistics of BT's conventional billing, procurement, delivery and payment processes, the creation of a network infrastructure for the growth of advanced business services requires close-coupled electronic trading systems. It has been apparent for some time that the trading processes associated with general communications services cannot be divorced from their primary technical features. The implicit requirement for management and control information has to some extent been reflected in the recent design of telephone exchange switching systems and network management centres.

Trading practice has, however, lagged behind the technical feasibility of information provision. In some cases, the traditional model of a universal telephone service provision has not been at all helpful in meeting the needs of customers whose primary requirement is for a closed user group, controlled community or service domain approach to communications services with, perhaps, secondary options for addressing a wider universe. The need, for example, to address specific geographic or sectoral service domains (particularly within ISDN user communities) may require controlled devolution of customer interfaces to selected service intermediaries.

This gap between the viewpoints of the traditional telecommunications provider and the needs of major customers has resulted in loss of competitiveness and market share in some of the new services introduced during the 1980s. Electronic trading and EDI provide a fresh opportunity to redress these design deficiencies, but this demands a wider recognition of the holistic approach to service and product design—an approach that recognises that the marketing methodology impacts directly on the technical design, and an approach that integrates finance and accounting operations more closely into the interface with the customer.

This development within BT is not unique. The experience in business systems design which companies gain as an integral part of EDI implementation is rapidly assimilated throughout trading communities. Some concerned commentators would project this experience forward to the emergence of (real or imaginary) 'electronic mergers' as the boundaries between organisations are blurred and the behaviour of manufacturing and trading systems becomes increasingly interdependent. In the more immediate future, however, EDI-based systems provide an element of organisational flexibility for industries that need to adapt to rapidly changing competitive needs.

It would be a mistake, or at least short-sighted, to view EDI from the limited technical perspective of a narrow band of highly specific message formats. From the provision of basic and managed network services, through to bespoke EDI services associated with major systems for customs import/export documentation or the pioneering interactive EDI services planned for Swissair[3], the impact of electronic trading is evident within all parts of BT's product and services portfolio. It comes as no surprise to learn that research into the use of electronic mail services such as Telecom Gold reveals that the principal customer applications are forms of 'sub-EDI'—informal inter-company trading processes that have developed as a step towards a fully functioning EDI service.

EDI, from a starting point of technical standards specification and managed networks development, is set to change the customers' perception of BT in the 1990s from a basic network services provider towards that of a business facilitator, providing much more of the essential infrastructure and expertise for creative and global business development.

ACKNOWLEDGEMENT

The author acknowledges the assistance of colleagues throughout BT and BT-Tymnet in the preparation of this article.

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APPENDIX 1

The Development of International EDI Standards

1961	Unitied Nations Economic Commission for Europe (UN/ECE) Committee on Development of Trade establish working party for 'Simplification and Standardisation of External Trade Documents'.
1968	US Department of Defense supports establishment of the Transportation Data Co-ordination Committee (TDCC).
1975–80	UN/ECE working party for Facilitation of International Trade Procedures forms two committees to define structures of business documents and develop a standard syntax for the formatting of data. Participation grows to 20 countries.
1978	Publication of Computer in International Trade and Transport—Data Standards after a design project commissioned by the UK Simpler Trade Procedures Board (SITPRO).
1978	The (USA) National Committee on International Trade Documentation (NCITD) develop cargo data interchange system (CARDIS)
1979	American National Standards Institute (ANSI) charter the Accredited Standards Committee (ASC) X12 to develop uniform EDI standards. The (X12) standards were adapted from earlier TDCC work.
1980–85	The UN/ECE, American X12 and TDCC evolve to meet two different

	priorities. The UN/ECE standards focus on government and international trade organisations (like ISO and IATA) while X12 develops to meet US business needs in domestic market.
1981	UN/ECE working party publish Trade Data Interchange Directory (TDID) with general message syntax for non-paper documents. This provided guidelines for both EDI and E-Mail messages. UN/ECE publish Trade Data Element Directory (TDED) with a different design approach to that used by ASC X12.
1982	The European Article Numbering Association (ANA) develop TRADACOMS standards and these are adopted by UK retail and grocery industry supported by SITPRO.
1983	UK automotive industry form group to develop EDI standards and (joined by other European countries) define the ODETTE message standards and file transfer protocol.
1984	ANSI, ASC X12 and TDDC form Joint Electronic Data Interchange (JEDI) to consolidate the data element and segment directories of the two US standards.
1985	European and USA automotive industries collaborate. (The ODETTE *invoice* message later merged with ASC X12 *invoice* to be the first UNJEDI *universal standard* message (UNSM) in 1986/87.) Standards experts meet in USA to explore scope for a single international EDI standard.
1986	American and European standards experts meet in London to draft UNJEDI syntax, control segments and an international invoice. UN/ECE established task groups to deal with convergence of syntax and message transactions.
1986–87	American and European UNJEDI task groups finalise the international syntax EDIFACT (electronic data interchange for administration commerce and trade) and the first universal standard message.
1987	EDIFACT syntax approved by the International Standards Organisation (ISO) as DIN 9735. ANSI produce migration plan for merger of X12 and EDIFACT standards.
1988	European contingent of UNJEDI establish Western European EDIFACT Board (WEEB) under auspices of the Commission of European Communities (CEC), Brussels.

Biography

After an early career as a telephone technician, David Brunnen's work on econometric modelling and market research sampling techniques for BT's Statistics and Business Research Department (and business studies at Kingston Polytechnic) led to a series of marketing and venture management assignments. He is a Council Member of the Parliamentary Information Technology Committee (PITCOM) and, in 1989, developed a methodology for the application and development of EDI services within BT and between its customers. The resultant EDI Active Support unit is at the centre of a network of expertise equipped with the management tools needed to fully exploit the potential for Electronic Trading both within and outside the BT Group.

Management of Information Technology Services

R. OPPENHEIMER, and B. P. WHITTAKER†

BT is becoming increasingly dependent on information technology (IT) to ensure that the data it holds is available where it is needed. IT service management is a new concept where computing and networking disciplines are combined to provide an end-to-end information service across multiple networking and computing domains.

THE BUSINESS NEED FOR INFORMATION TECHNOLOGY SERVICE MANAGEMENT

The increased use of information technology (IT) by BT in its operations brings with it management problems of its own. Users throughout the company require access to different services while support systems, operating procedures and organisation units are constantly being updated. The key to successful IT service management lies in the ability to mix and match different communications networks and computing facilities to provide end-to-end service.

Often major IT investments like large new computer systems are introduced *in vacuo*, and the means to support them and their users have had to be set up from scratch for each new development. The service management programme provides an environment in which the company's information systems can be introduced and operated in a way which improves the chance of achieving the maximum benefit from them.

Service management is not only a concept for supporting the company's internal needs. Many large organisations are equally dependent on efficient operation of their information infrastructure. Service management and the equipment and methods developed to support it should be highly saleable.

SERVICE MANAGEMENT PRINCIPLES

The model used to define the way in which service management works has been based on some initiatives in which the company has already invested much time and effort. In particular, it builds on the Strategic Systems Plan (SSP)[1] and the Co-operative Networking Architecture (CNA) model for open systems management[2]. It also builds on a vision of the way service should be offered to customers in general and a new geographic organisation for providing internal services. This new organisation provides services independent of the units by which the group carries out its mainstream business. Capitalising on existing strategies helps ensure that the final concept aligns well with other initiatives which BT is pursuing such as management of the public network.

A clear vision encompassing several principles was adopted from the outset.

- There is to be a single point of contact into the service management organisation for all users. This point of contact will be independent of the service which the user is interested in.
- The principle of problem ownership will apply such that the initial contact point will retain ownership of all problems reported until they have been cleared with the user. This is to ensure that users do not see their contacts being lost within the organisation.
- The basic measure of quality of service must be the service as perceived by the end user, not the statistical performance of the individual components of the service like the network or the computer centre.
- The organisation for provision of service will be on a geographical basis, not by type of service or by type of user.
- The mechanism by which service is provided is to be the result of a proper process model so that the working responsibilities and requirements for computer support are clear. This process model is discussed in a later section of this article.
- The range of services provided by the service organisation will be the subject of a structured portfolio. This not only makes the management and evolution of services easier, but it helps potential users to design their requirements against a known set of services with defined management and costs.

The definition of a structured service portfolio is fundamental to the service management concept and is explained in the next section.

TYPES OF SERVICE—THE SERVICE PORTFOLIO

It is important for any organisation which serves customers to have a complementary, comprehensive range of services which do not compete with one another when offered to its customers. To this end, a structured service portfolio has to be set up for the internal services.

In principle, all IT services are made of various combinations of communications and computing.

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† Computing and Information Services, British Telecom UK

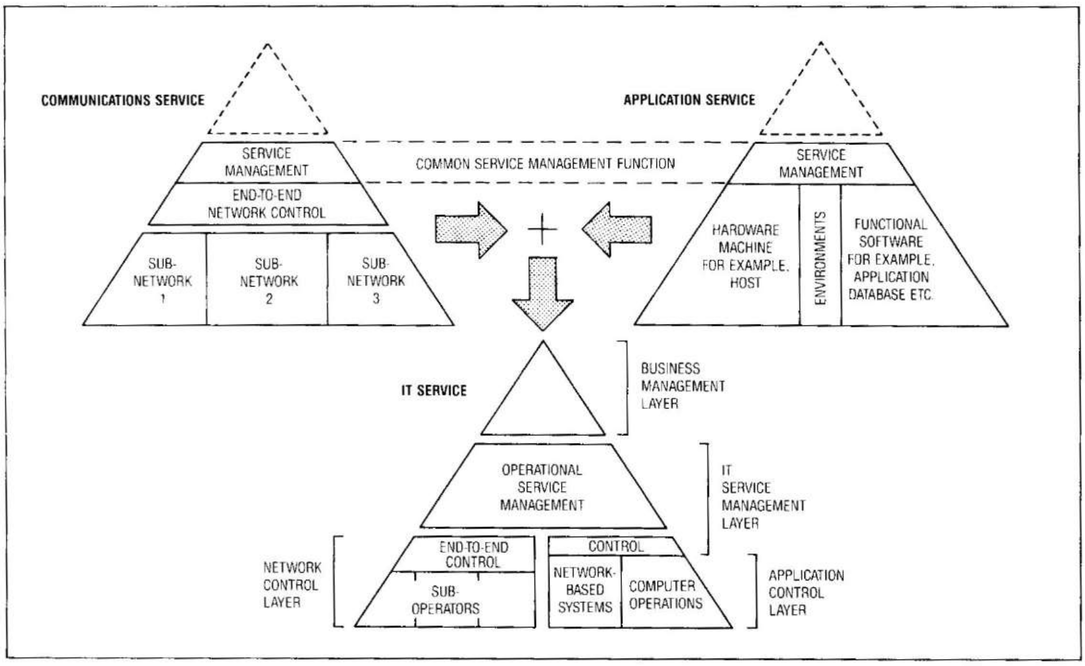

COMMUNICATIONS SERVICE
APPLICATION SERVICE
SERVICE MANAGEMENT
COMMON SERVICE MANAGEMENT FUNCTION
SERVICE MANAGEMENT
END-TO-END NETWORK CONTROL
SUB-NETWORK 1
SUB-NETWORK 2
SUB-NETWORK 3
HARDWARE MACHINE FOR EXAMPLE, HOST
ENVIRONMENTS
FUNCTIONAL SOFTWARE FOR EXAMPLE, APPLICATION DATABASE ETC
IT SERVICE
BUSINESS MANAGEMENT LAYER
OPERATIONAL SERVICE MANAGEMENT
IT SERVICE MANAGEMENT LAYER
NETWORK CONTROL LAYER
END-TO-END CONTROL
SUB-OPERATORS
CONTROL
NETWORK-BASED SYSTEMS
COMPUTER OPERATIONS
APPLICATION CONTROL LAYER

Figure 1
IT service definition

The service portfolio comprises a number of major classes of service: voice services, data services, specialised services and IT services. A major host-computer-based suite like the Customer Service System is an example of one type of IT service. Video conferencing is an example of a service which only contains communications components. The management structure for the portfolio is shown diagramatically in Figure 1. The portfolio could be regarded as a co-ordination of networking and computing infrastructures which support a range of business applications.

Generally, all the services contain a communications element and some contain computing elements as well.

The portfolio is useful to the service organisation and its customers alike. Application designers will have a set of well-defined (and tested) options available for their systems to use. The service organisation is able to price its services and make the appropriate agreements with those units who supply parts of the service.

Although the aim is to be able to provide each customer with a specially tailored package of services, it is still necessary to select those services from a predefined portfolio. The lack of a predefined set of services can cause problems at operational centres where staff could have to deal with a plethora of different customers with individual requirements. It also causes problems at a business level where increasing service complexity causes significantly increased business overheads. The portfolio will evolve with advancing technology and represents a compromise between the technical wish list and business needs.

THE PROCESS MODEL

In order to specify a complementary set of support tools and procedures for service management, it is important to understand a process model for the operation in some detail. Fortunately, it was possible to capitalise on work which had been done on modelling the operations of BT's public operations as BT is itself a service organisation.

Two key pieces of work from within BT were used for the essence of the model. Other work such as Alvin Toffler's report[3] to AT&T in 1972 was also influential in shaping the strategy.

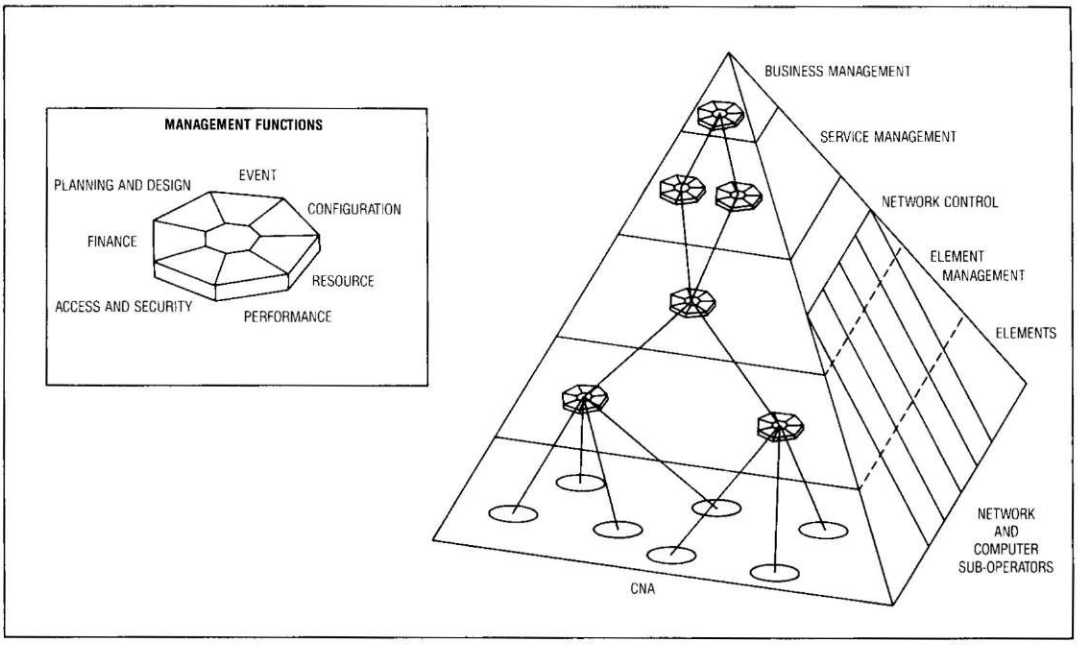
The studies from within BT were the Strategic Systems Plan (SSP)[1] and the CNA model for network management.

The SSP is based on a functional breakdown of an ideal network operating company. It provides at least four levels of decomposition; it also covers data flows between processes and a data model. The model has been used to define a set of business system areas which exploit synergies between processes and data groups to provide high-level definitions of a complementary set of support systems.

The CNA model describes a hierarchy of functions needed to control a modern communications network. This hierarchy extends from the technical control of network elements up to the high-level business-oriented functions needed to manage the enterprise (Figure 2). The model is more developed at the lower levels simply because of the drive to use it in the development of new network elements and the message sets necessary to control them. However, many of the functions defined in the SSP can be mapped onto the hierarchy. This is helpful because it provides a basis for defining system boundaries and data flows. The mapping also provides a useful amalgam of a bottom-up and a top-down business view.

Although the CNA hierarchy principle is usually applied to networks of communications devices, the model can apply to networks which include computing elements and application programs as well.

Figure 2
The network management hierarchy for managing an information network



CELL STRUCTURE

It became apparent at an early stage that the BT internal network is too big to be centrally managed from one point. The optimum solution seemed to be to divide the operation into a number of geographical zones or cells and then to interconnect the organisation and support tools to provide a single logical management function. The cells are made up of a number of different types of unit as follows.

The *front office* is the part of the organisation which faces the IT users. It is therefore service oriented, services being what the users perceive. It provides a single point of contact for the users. Each cell is intended to have a number of front offices so that they can be near to the users. The actual number and size will depend on the volume of work generated in serving the users and the sophistication of the support tools that they are equipped with.

The staff in the front offices need to be user-oriented people and, because they are located near to the users, they will have valuable local knowledge. The front offices will be networked to the back office and to each other to provide a single logical office. The front offices will be provided with tools which give service health information and enable input to the major support tools for order handling, fault handling and workforce management. It is intended that the front office should be able to handle at least 80% of user contacts without further support.

The *back office* is responsible for providing the end-to-end aspects of managing networks. It will be responsible for performing the technology-facing functions needed to run an end-to-end service and interfacing with other organisations which operate parts of the network or computer facilities (sub-operators). The relationship between the back office and the sub-operators needs to be sufficient in terms of authority and information flow for the back office to be able to co-ordinate an end-to-end service.

Examination of the process model clarifies the activities and data which the back office needs access to and hence provides a framework for both support tools and service level agreements. In general, processes which form part of the network control layer of the CNA hierarchy involve information sharing between the back office and the sub-operator.

One special type of sub-operator is the computer centre operator. In process terms, operation of the computer centre is similar to the control of a network; the way in which the network and the computer operations are co-ordinated and the support tools which they share are thus easily understood by using the process model.

STAFFING THE FRONT OFFICE

Experts who have studied emerging changes in working habits point to the trend away from jobs with fixed hours which involve commuting to large workcentres. In fact, the indications are that workers of the future, especially in service industries, will expect to work in comparatively small local workcentres and have flexible working arrangements.

The trend towards local workcentres is an advantage to the organisation because the front-office staff will have local knowledge and the cost of staff having to commute to and work in large centralised workcentres will be saved. The use of automatic call distribution systems and terminal networks means that this mode of operation is now easy to realise and need not cause problems of work redistribution when the workload changes. The networking technology provides a means of creating a large efficient logical service centre while still preserving valuable local knowledge.

ORGANISING FOR SERVICE MANAGEMENT

The service management organisation has two main types of customer. The first type is the owner of a project who will require project and account management support to get a facility up and running with ongoing operational support. The second is the end user or receiver of the facility. The service management organisation has to be specifically organised to cater efficiently for both these types of customer.

The project-owner class of customer deals with the service organisation via an account manager (Figure 3). The account manager is then responsible for assessing the customers' needs, allocating the appropriate portfolio items to them and project managing the work. This conforms to the SSP concept that allocation of capacity is part of serving customers.

The end-user type of customer addresses all dealings through the front office. The front office is equipped to service requests for change, fault and problem reports and handling of authorised requests for service. The front office has operating arrangements with local installation and maintenance staff and will be aware (via the account managers) of authorised requests for service. The front office will be able to provide service at very short notice by having pre-provided capacity and being pre-warned by the account managers of the demands for service.

TOOLS

The process model is key to defining the requirements for the service management support tools.

In the past, the approach has been to try and obtain a set of unambiguous requirements from the users and then build the system to these. This method contains two fundamental flaws: firstly, the complexity of the systems are such that they cannot be understood simply from a user's perspective, and, secondly, the introduction of the system may (and arguably should) change the user's working methods and hence the user's requirements.

Using a process model simplifies the identification of tools which do similar jobs, how they should interwork and processes which are ripe for better computer support. An initial analysis of the tools available showed that there are many tools which support a number of processes, but only for a given type of networking equipment. The analysis also showed that some processes, generally ones which are not directly connected with controlling equipment, are hardly supported by information systems at all.

Given the plethora of existing tools used for controlling the existing internal networks, a rigorous analysis of them all was neither practical nor worthwhile. Instead a number of promising candidates were chosen for detailed attention. These tended to be tools for which BT had a direct influence on their evolution.

Management of specialised networks like the internal network involves control of a number of different types of network technology often controlled by different people. The types of tool required to handle this situation fall into three categories.

The first type is a structured electronic mail system. These vary in sophistication up to

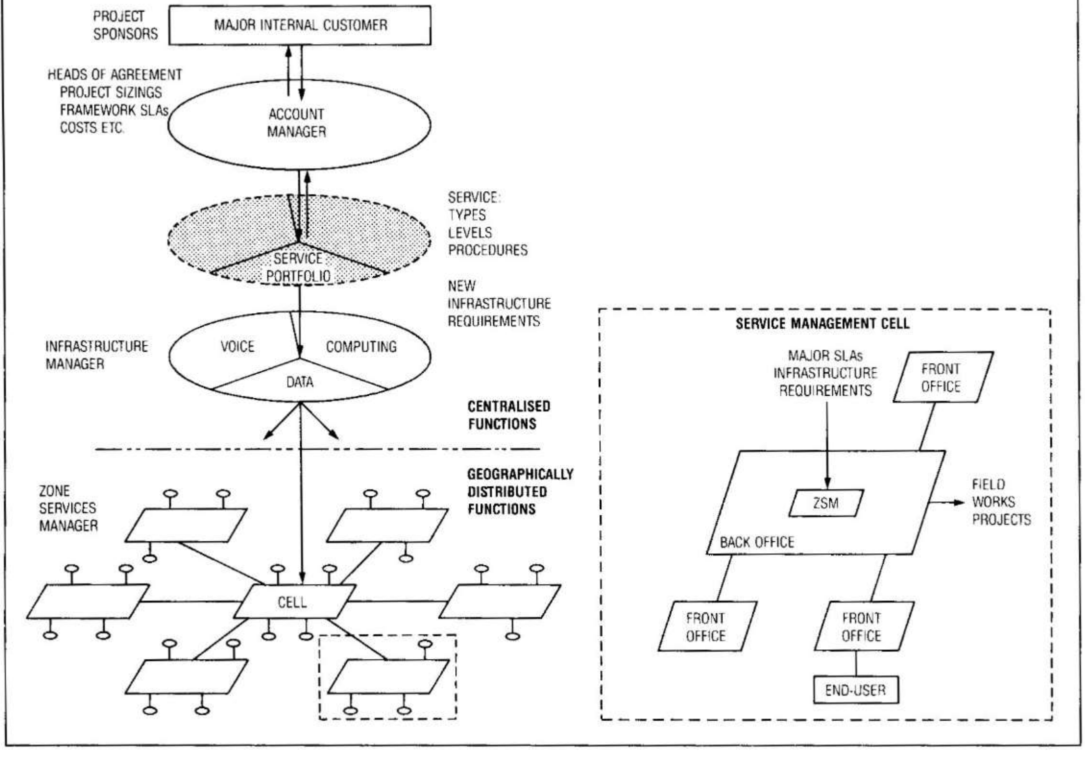


Figure 3
Management of a major project for a customer

ZSM: Zone services manager SLA: Service level agreement systems with automatic prompting and escalation with customised forms. The function of this tool is simply to ensure that information is rapidly conveyed to the right people in a controlled way. One such system is the ServiceDesk system described elsewhere in this issue of the *Journal*[4] and is specifically designed for this type of application.

The second type of tool is an information-handling tool which is used for off-line data manipulation. This is used for performing manipulations which are not directly network affecting such as generating statistics or designing configurations.

Another, third, class of tools are those which are used for real-time control of network devices. These are generally the most numerous and are often supplied by manufacturers for controlling their own devices. The problem with this class of tools is the sheer number of them required to control a network with any significant number of types of equipment and their inability to interwork. Some manufacturers have already recognised this problem and are starting to produce tools which either bring together the manufacturers' specific tools or directly control devices which conform to the correct standards. One such set of tools is known as *Concert*™ and is being developed by British Telecom.

All of these tools require access, in varying degrees, to the service database. This contains all data needed for operating the service including an inventory of network components, service levels, user profiles and the like. In practice, most of the tools hold some of this data and the challenge is to ensure that data is distributed so that each process has sufficient access to the data it needs.

During the evaluation of tools required to support the service management organisation, each part of the organisation was assessed for the type of tools it required. The structured mail system and an inventory system need to be shared between front office, back office and the sub-operator. Device control tools are generally used by the sub-operator while the information handling tools are shared between sub-operator and back office.

The tools required in the front and back offices and by the sub-operator were assessed for each major type of network technology in use. In some cases, it was difficult to arrange a complementary set of tools and in these cases the study provided a focus for development priorities by the tool developers.

It has become clear during this work that to have a complementary and, where possible, integrated tool set is of great importance. One of the most important reasons is that it supports a mode of working. Where an organisation is not properly supported with information systems, the roles of the people within the organisation rapidly become confused and the organisation becomes inefficient. Providing a good set of information systems ensures that the correct way of doing a task is also the easiest so that human nature and technology work together to provide an efficient operation.

CONCLUSION

Service management is important to the business primarily because it is vital to ensure that all users within the company have quality information systems available to them. The approach outlined in this article is the product of a number of different studies into the way in which an information-based organisation of the future should work.

Service management is not only important to British Telecom for its own use, but it will be important to other companies who are becoming more reliant on their information systems. As such a set of service management products and procedures represent a valuable market opportunity for the company.

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Biographies

Richard Oppenheimer joined the then British Post Office as a student in 1978. He studied Electrical and Electronic Engineering at Sheffield University. In 1983, he moved to BT International where he worked on Telex transmission systems. In 1987, he moved to BTUK Network where he worked on the digital exchange support system and latterly on INTERNET. He joined the Internal Communications Provisioning Authority in York when it was created in 1989. He now works on business modelling and strategy for managing BT's internal IT services. He is a Member of the Institution of Electrical Engineers.

Barry Whittaker joined the Post Office Telecommunications department in September 1979. After a short time in telephony switching maintenance, he completed an Electrical and Electronic Engineering degree at Manchester University. He joined Trunk Networks Planning HQ in London and was involved in the planning and design of data networks for the administration and control of the new digital main switching units. With the advent of BT's OSI initiative (CNA) he was involved in developing open interfaces between the various exchange and transmission network support systems. Recent work with the Internal Communications Provisioning Authority has involved him in network and service management design for BT's internal services. He is an Associate Member of the Institution of Electrical Engineers.

ISDN for the 1990s

I. G. DUFOUR, J. F. MARSHALL, and F. WELSBY†

British Telecom is re-launching its integrated services digital network (ISDN) to conform to the latest international standards. This article reviews the background to the latest developments and outlines the way ahead.

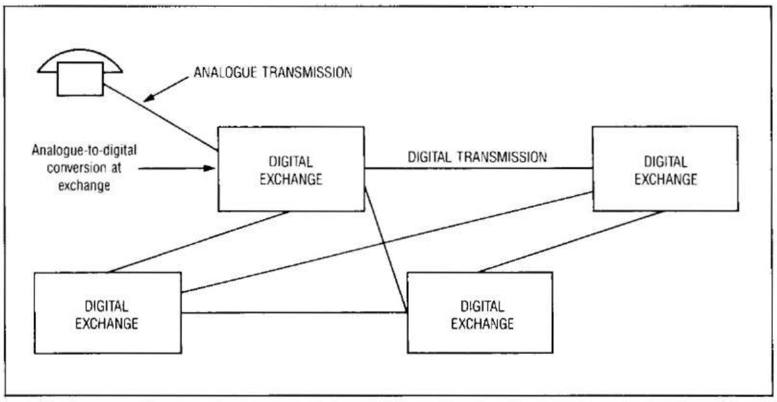
INTRODUCTION

Ever since the early-1970s, when the concepts of digital telephone exchanges linked by digital transmission systems took root, people have talked about digital customer access to an integrated services digital network (ISDN) (Figure 1). The reader might be forgiven for thinking that we have never managed to get beyond the concept and talking stages to judge by the volumes of articles, conference papers and standards that have been published over the intervening years with, as yet, little sight of real customer services. However, this view underrates the long time-scales and massive investments implicit in modernising and developing telecommunications networks and in introducing new service capability. What has probably happened is that the long gestation period has led to publicity and expectations running ahead of the global network's capability to deliver. Fortunately, a period is now approaching that is opportune for ISDN to start taking on the role for which it has been billed for so long. But what is ISDN?

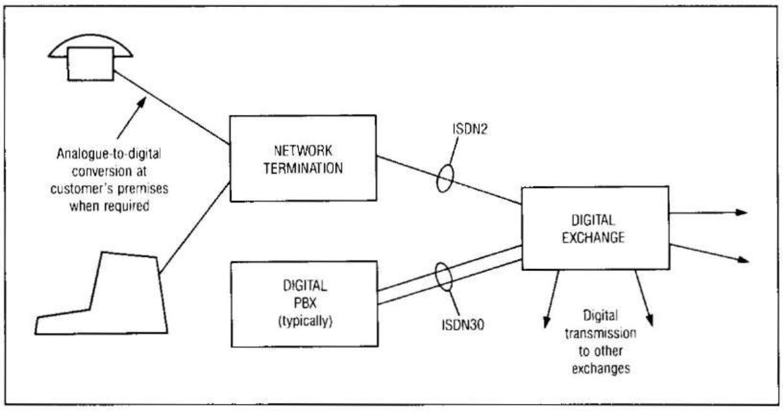
The much quoted and comprehensive definition of ISDN from the CCITT is worth repeating here for completeness:

> 'A network evolved from the telephony integrated digital network (IDN) that provides end-to-end digital connectivity to support a wide range of services, including voice and non-voice services, to which users have access by a limited set of standard multi-purpose customer interfaces.'

From this stem the challenges and complexity facing the network designer. On the one hand, the ISDN must carry straightforward voice communication and be able to interface with the worldwide telephony network. On the other, it must accommodate a wide-range of non-voice services for which numerous standards have had to be established to allow worldwide compatibility for end-to-end services. These two extremes also provide the opportunities for ISDN to succeed. At one level, ISDN, simply meaning digital delivery of telephony to the customer, might succeed if the network operator can reduce costs, especially if they can be reduced to the extent of lowering customer prices. At another level, it might succeed through the generation of new services and applications, predominantly non-voice, and new revenues from them.



(*a*) Digital switching and core transmission with analogue local line


Analogue-to-digital conversion at customer's premises when required
NETWORK TERMINATION
ISDN2
DIGITAL EXCHANGE
DIGITAL PBX (typically)
ISDN30
Digital transmission to other exchanges

(*b*) ISDN with digital transmission to customers

Figure 1—Evolution to full ISDN

Another ingredient for success is the recognition that the requirements are not just for a network capability to defined international standards, but also for customer premises equipment (CPE) and user-orientated applications. Only when all these converge will a customer derive genuine benefit from ISDN. Above all, ISDN is not a single service but a family of services which are an extensive and natural development of the switched network.

Internationally, networks are just coming to the stage where they will soon be able to support ISDN and similarly CPE, and applications are just becoming available in numerous countries.

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BASIC-RATE AND PRIMARY-RATE SERVICES

ISDN services are divided into *basic-rate* and *primary-rate*.

Basic-Rate (2B+D)

Basic-rate access offers two 64 kbit/s B-channels and one 16 kbit/s D-channel, and is known as *2B+D*. It is presented to the customer at a standard interface known as *I.420*. The B-channels can be used by the customer for any digitised information including voice. The D-channel is mainly used for signalling, but can be used for access to packet networks and for some user-to-user information. Basic-rate was designed to be carried over the conventional copper pair normally used for a single analogue telephony line, but it can of course be transported via other media such as optical fibres or radio via multiplexing techniques.

British Telecom has operated a pre-international standard basic-rate service[1,2] since 1985. This offers one 64 kbit/s B-channel, one 8 kbit/s B-channel (switched as 64 kbit/s) and one 8 kbit/s D-channel. The customer interface is X.21. This service has been limited to a few hundred customer lines and will be phased out. The basic-rate service just being launched on System X is called *ISDN 2* and is to the internationally conformant 2B+D I.420 customer interface standard[3].

Primary-Rate (30B+D)

Primary-rate service offers thirty 64 kbit/s B-channels and one 64 kbit/s D-channel (except where the North American digital system hierarchy is used when it offers twenty-three 64 kbit/s B-channels and one 64 kbit/s D-channel). It is principally used to interconnect digital integrated services private branch exchanges (ISPBXs) over 2 Mbit/s links to digital local exchanges. BT launched this service in October 1988 on System X and will launch it in January 1991 on AXE10. The internationally conformant signalling presentation for primary-rate is I.421, but currently the BT service, called *ISDN 30*, uses a pre-international standard. This standard signalling system, called *Digital Access Signalling System No. 2* (DASS2), was adopted by ISPBX suppliers some time ago and accounts for BT's ability to claim a world first for the launch of a commercial primary-rate service. While the signalling system itself is not to the international standard, which is only just being finalised, the majority of the services provided are conformant. BT will provide an I.421 presentation in due course.

The primary-rate service is the epitome of the ISDN opportunity. Its initial application is for fast ISPBX digital access to the IDN for telephony, but all the non-voice capability is there waiting to be used as applications emerge.

Bearer Services, Teleservices and Supplementary Services

The service structure of ISDN is categorised as basic telecommunications services divided into two broad families, called *bearer services* and *teleservices*. In addition, there are *supplementary services* which modify or supplement a basic telecommunications service (Table 1). Bearer services are transparent services carrying the information flow between terminals. Circuit-mode and packet-mode bearer services are

TABLE 1

Basic Telecommunications Services

Bearer Services

- — Circuit mode speech
- * — Circuit-mode 64 kbit/s unrestricted
- * — Circuit-mode 3·1 kHz audio
- — Circuit-mode 2 × 64 kbit/s unrestricted
- — Packet mode
    - X.31 case A (B-channel)
    - X.31 case B (D-channel)
    - X.31 case B (B-channel)

Teleservices

- — Telephony (3·1 kHz bandwidth)
- — Teletex
- — Telefax (Group 4 facsimile)
- — Telephony (7 kHz bandwidth)
- — Audiographic teleconferencing
- — Teleaction
- — Videotelephony
- — Computerised communication service

Supplementary Services

- — Advice of charge service
    - Charging information at call set-up time
    - Charging information during the call
    - Charging information at end of call
- — Number identification services
    - * Calling-line identification presentation
    - * Calling-line identification restriction
    - Connected-line identification presentation
    - Connected-line identification restriction
- — Closed user group
- — Call waiting
- — Completion of call to busy subscribers
- — Conference services
    - Conference call, add-on
    - Meet-me conference
- — Direct dialling in
- — Diversion services
    - Call forwarding unconditional
    - Call forwarding busy
    - Call forwarding no reply
    - Call deflection
- — Freephone
- — Malicious call identification
- * — Multiple subscriber number
- — Sub-addressing
- * — Terminal portability
- — Three-part service
- — User−user signalling

* Minimum service offering to conform to European Memorandum of Understanding

available. Teleservices are standard services such as telephony, facsimile, teletex and videotex. These user-to-user services are made available through terminal equipment and procedures employing bearer services. The information flow between terminals is handled by the bearer service with higher-level conventions for the teleservices handled by the terminals. Supplementary services are user facilities or features which cannot be offered as a stand-alone service. A wide variety is potentially available some of which are listed in Table 1.

EUROPEAN MEMORANDUM OF UNDERSTANDING

In April 1989, members of the European Conference of Posts and Telecommunications (CEPT) agreed the terms of a Memorandum of Understanding (MOU) to provide European ISDN services. Operators covering a population of over 350 million from 18 countries, including BT, are signatories. The MOU provides a framework for the opening of commercial public ISDN services to common standards across Europe by 1992. It provides for:

(*a*) a common range of services which all signatories will provide (asterisked in Table 1), and a list of further optional services which will be provided to common standards as the market demand develops (the remainder of Table 1);

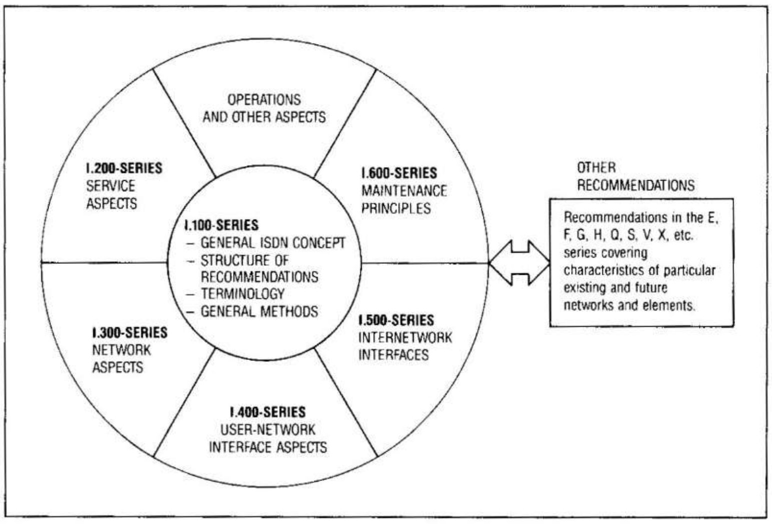
(*b*) support for common standards for customer equipment, the aim being that any terminal made to agreed standards (*Normes Europeenes Telecommunications* (NETs)) can be used in any country where the operator has signed the MOU; and

(*c*) agreed arrangements for interconnecting national systems in order to provide international services.

In some cases, the relevant technical standards are not yet set, or not yet finalised, and the co-signatories have committed themselves to produce them, through the European Telecommunications Standards Institute (ETSI), in adequate time to meet the target dates for service.

STANDARDS OVERVIEW

It has long been taken for granted that a telephone call can be made from any telephone to any other anywhere in the world. Over the years, this has involved agreed standards, notably for transmission quality and signalling. ISDN, however, as discussed earlier, is not a unitary service, but a virtually open-ended range of services. These services embrace not just network capability, but also terminal equipment, and each service is, furthermore, extremely complex and described in terms of the Open Systems Interconnection (OSI) 7-layer protocols. To permit the same worldwide connectivity expected of analogue telephony thus calls for major agreements on network standards and, to a slightly lesser extent, on CPE standards. Over the last 20 years, the CCITT (International Telegraph and Telephone Consultative Committee) has devoted much effort to this task. The sheer scale of the principal standards relating to ISDN can be seen from Appendix 1. However, the main ISDN-related standards are the I-series, structured as shown in Figure 2. These were last updated in November 1988 at the CCITT 9th Plenary Assembly in Melbourne and subsequently published in what is commonly known as the *Blue Book* after the colour of its bindings. The I-series alone runs to several hundred pages. There have already been useful articles[4,5,6] on the CCITT Recommendations relating to ISDN but the serious student is advised to become familiar with the source CCITT documentation[7].

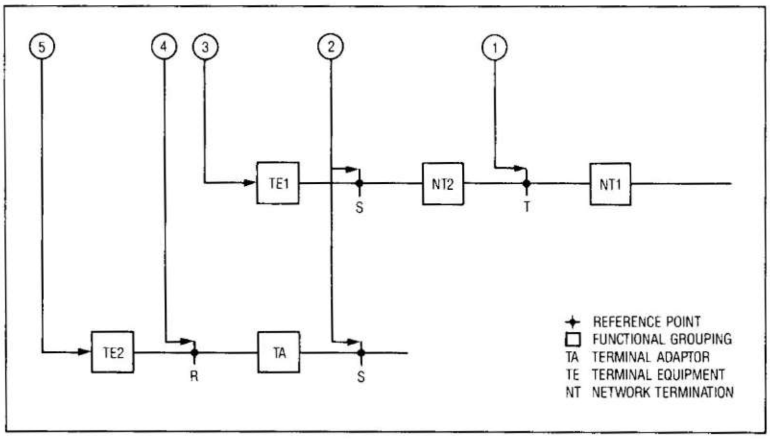


Note: Models, reference configurations, tools and methods are contained in the appropriate I-series Recommendations

Figure 2—Structure of CCITT I-series Recommendations and their relationship with other Recommendations

The standards for customer access need to be understood as they are so widely quoted. In general, customers can access telecommunications services at different access points as shown in Figure 3 which takes into account that the network provider may offer to a customer connected to an ISDN the whole or only part of the means to support the service fully.

Figure 3
Customer access to services supported by an ISDN



The definitions of the access points in Figure 3 are as follows:

- Access points 1 (reference point T) and 2 (reference point S) are the access points for bearer services supported by an ISDN. The choice between T and S depends on the ownership and point of provision (to the customer) of the communications equipment at the customer's premises.
- At access point 4 (reference point R), depending on the type of terminal adaptors provided, other CCITT standardised services may be accessed; for example, according to the X- and V-series of CCITT Recommendations.
- At access points 3 and 5 (user to terminal interface), teleservices are accessed (the teleservice concept includes some of the terminal capability).

All customer equipment connected to an ISDN interface at one of those access points should meet the specifications of the protocols at that interface for all the layers that are included in the definition of the service used.

BT, in line with European requirements, provides an interface at the T reference point with functions beyond that—that is, NT2, TE1 or TA and TE2—regarded as CPE.

North America has adopted a regional standard for basic-rate service between the NT1 and the copper pair which is commonly known as the *U reference point*. This has been driven largely by the regulatory position in the USA where the network provider is prohibited from owning any equipment within premises and thus terminates a copper pair on the outside of a premises. This has necessitated the adoption of a North American standard 2B1Q (2 binary, 1 quaternary) line code, developed at British Telecom Research Laboratories, which is now becoming a de facto world standard.

Nevertheless, the U reference point is proving troublesome for service maintenance where some NT1 functions are important; for example, for delivery over other than a copper pair (that is, fibre or radio), for an orderly delivery of the many possible services and for the introduction of CPE which can be moved between premises irrespective of the supplier of the NT1 function. These is no movement in Europe towards a U reference point.

In common with other European countries, BT is committed to provide a network and, where appropriate to its CPE portfolio, CPE which conforms to the S/T reference points. In accordance with the MOU, a test regime is being set up using NETs as the standard reference. The key terminal equipment NETs are NET3 for basic rate and NET5 for primary rate.

NETWORK IMPLEMENTATION

Other articles[3,8] deal in much greater detail with the BT implementation of ISDN. There are, nevertheless, some significant issues about the implementation of ISDN in the network that are worth reviewing here.

The major issue is that of mapping a complex range of service features (see Table 1) onto a network made up of System X exchanges, AXE10 exchanges, international gateway exchanges, CCITT Signalling System No. 7 links between them all, the operations and management centres (OMCs) and, initially at least, special ISDN multiplexers. All of these have extensive software content and, excluding the latter, are huge project areas in their own right with a momentum of their own outside ISDN. The introduction of each ISDN service feature thus calls for careful project management across all the areas mentioned as well as others, such as the local loop, customer service and procurement, in order to achieve end-to-end service provision. A closely controlled programme involving phases of service introduction has thus been adopted.

Another issue relates to the adoption by BT of a multiplexer solution for initial implementation compared to the alternative of using ISDN line cards on the digital exchange. The timescales for introducing the latter were felt to be longer and the ability to get widespread geographic coverage somewhat slower than the multiplexer approach. The corresponding disadvantages of the multiplexer, namely increased network complexity and cost, are such that the line-card solution remains the longer-term aim. The adoption of the multiplexer solution therefore allows earlier implementation of internationally conformant services than would otherwise be the case to the mutual benefit of BT and its customers who can start to understand and realise the potential of ISDN.

One anomaly that arises from the timing of the introduction is that the multiplexer chosen by BT uses a 3B2T (3 binary, 2 ternary) line code whereas future implementations will adopt the 2B1Q line code. A later article in this *Journal* will update the information on 2B1Q line transmission systems given in Reference 9.

The implementation of ISDN has also resulted in the need for specialist test equipment both for the development and integration of network products and for subsequent field operations. BT's early implementation of ISDN has meant that standard products were not available and so considerable effort has been put into developing appropriate test equipment. Examples are the Digital Communications Tester[10] for testing the ISDN signalling protocols, the Martinet for testing the CCITT No. 7 protocols and the IMATE field tester[8]. BT's contribution to the design of these testers has subsequently resulted in testing products being sold on the world market.

INTERNATIONAL LINKS

Many other countries are building ISDN capability into their networks and many of them, like

BT, started some years ago with pre-Blue Book standards. Similarly, they are upgrading their networks and this makes international connectivity possible. Customers of BT's ISDN services have been able to make calls to France, Japan and the USA since 1989 and this was extended in September 1990 to Australia, Belgium, Denmark, The Netherlands and Sweden. The end of 1990 will see Finland, Germany, Hong Kong and Singapore added to a list which will continue to lengthen. The initial service capabilities cover voice and straightforward 64 kbit/s channels.

CUSTOMER PREMISES EQUIPMENT (CPE) AND APPLICATIONS

It was noted earlier that ISDN relies not just on a network capability but also on the availability of CPE and applications. This is an area which is still in its infancy but numerous developments have already emerged.

Examples are:

Terminal Adaptors and Digital Telephone Sets Terminal adaptors will be widespread in the early days of basic-rate ISDN as they allow existing terminal equipment with, for instance, V.24, V.35 or X.21 interfaces, to use the I.420 interface. As many terminal adaptors have a handset for voice capability, it can become a matter of semantics whether a unit is called a terminal adaptor with a handset or a digital telephone with a terminal adaptor. Perhaps the latter will be distinguished by their line-powering capability and their ability to handle additional features such as 7 kHz hi-fi bandwidth speech.

PC–PC File Transfer The widespread adoption of desk-top personal computers (PCs) is increasing the importance of file transfer between them. ISDN provides a high-speed digital highway for this application and increases the scope for combining voice with text or graphics. One example is the use of a light pen for graphics on one screen which simultaneously appears on a remote screen via one B-channel link with voice contact via the other B-channel.

LAN Access Dial-up access at 64 kbit/s to company local area networks (LANs) is likely to provide the user with facilities indistinguishable from direct connection. Application of the ISDN closed-user-group capability can provide significant security benefits to remote access systems. These developments are likely to give impetus to the moves towards working from home.

Group 4 Facsimile These provide a quality and speed of operation well beyond current experience. A high-quality A4 image can be transmitted in 6–8 seconds. Development machines with an I.420 interface have been tested successfully, but commercial machines are only just becoming available in the UK.

Video Telephony and Videoconferencing Terminals are already available which provide good quality vision for conferencing purposes. As costs of the terminal equipment reduce with volume, this could become a major growth area. A typical application would require the two basic-rate B-channels (equivalent to 128 kbit/s) from which 16 kbit/s is allocated for speech with the remainder used for the video information. Equipment is already becoming available for this application. A BT development product is shown in Figure 4.

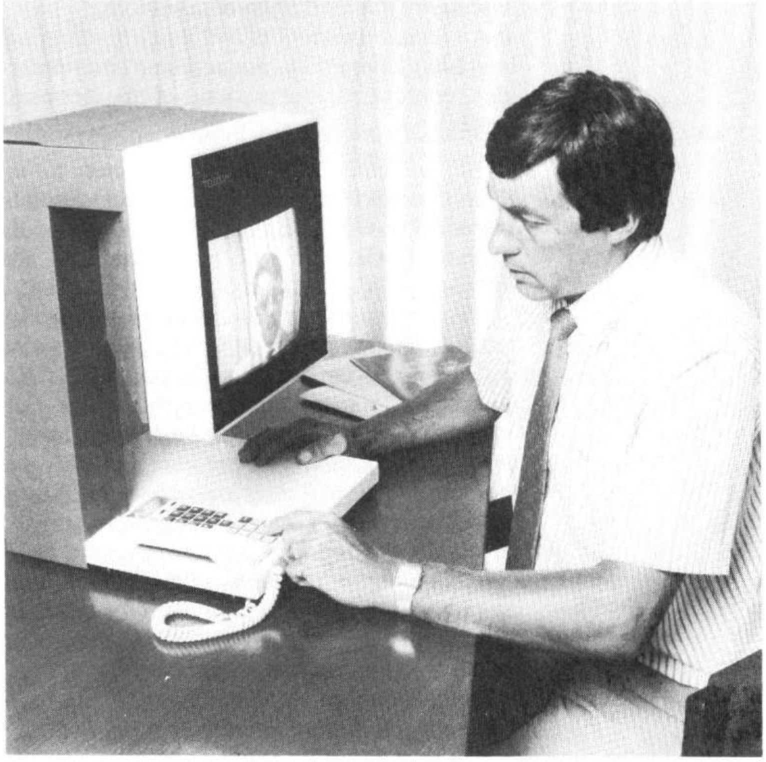


Figure 4
Prototype of a videotelephony/ videoconferencing terminal under development by British Telecom

Looking further ahead, applications will emerge for packet-mode and frame-mode services. Packet-mode offers X.25 data users access to packet switching facilities either at 64 kbit/s via the B-channels or at a lower rate via the D-channel. Network capability for D-channel packet is, however, a later development. Frame-mode is still an emerging approach based on a separation of signalling information from the packetised data. It is compatible with, but more flexible than, X.25 and is capable of high data throughput rates. It could become a bridging application between packet services, ISDN and emerging broadband data services.

THE FUTURE

The extent of ISDN realisation ultimately depends on market demand, but a path ahead can be postulated. Over the next few years, more and more CPE and applications will become available to make use of the network capability. At the same time, additional service features will be incorporated into the network to encourage further applications which, in turn, will stimulate demand. By the mid-1990s, increased demand, attention to reducing network costs and pan-European and international availability should mean that ISDN 2 and ISDN 30 will become the norm for business lines. By that time, packet and frame services will have been introduced leading to compatibility with emerging asynchronous transfer mode (ATM) switching systems. This, in turn, will set a path for possible further long-term developments towards a broadband ISDN capable of carrying a wide variety of high bandwidth services many of which are beyond our current ability to foresee.

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APPENDIX 1

References to other Recommendations Relevant to ISDNs

Access, user network (I.400-series)
— Q.920, Q.930

Adaptation, terminal (I.460-series)
— X.30, X.31
— V.110, V.120

Bearer services
— X.25, X.31, X.300
— G.711

Charging (I.141, I.326)
— D.93, D.200-series

Digital switching
— Q.500-series

Digital transmission
— G.700-series, G.800-series, G.900-series

Exchange, digital local
— Q.511 to Q.517

Interworking: digital hierarchies
— G. 802

Interworking, ISDN and other networks (I.500-series)
— X.1, X.2, X.10, X.15, X.25, X.30, X.31, X.71, X.75, X.81
— X.180, X.181, X.300-series
— V.110, V.120
— U.12, U.202
— Q.921, Q.931

Interworking, signalling systems
— Q.120 to Q.180, Q.251 to Q.300, Q.310 to Q.490
— Q.600-series, Q.700-series
— X.75

Management and maintenance (I.600-series)
— M.20, M.21, M.22, M.24, M.30, M.36, M.40
— M.122, M.125
— M.250, M.251, M.550, M.555, M.557
— M.770, M.782
— G.601, G.700-series, G.821, G.900-series
— Q.512, Q.542, Q.940

Modelling (I.130-series, I.140-series, I.300-series)
— Q.65, Q.71, Q.80, Q.500-series, Q.700-series
— X.200, X.300
— Z.100-series

Numbering (I.330-series)
— E.163, E.164, E.165, E.166, E.167
— F.69
— X.121, X.122, X.200
— Q.921, Q.931, Q.932
— T.90

Parameter exchange (I.515)
— V.32, V.100, V.110, V.120
— G.725
— X.21, X.21*bis*, X.25, X.30, X.31
— Q.931, Q.932, Q.764

Performance (I.350-series)
— G.100-series
— G.821, G.822, G.823 and G.824
— P.56, P.66 and P.84

Protection
— K.20
— K.22
— K.23

Routing (I.335)
— E.164, E.170 to E.172, E.502
— G.801
— X.110
— Q.600-series, Q.700-series, Q.930, Q.931

Signalling, user-network (I.440-series, I.450-series)
— Q.920 to Q.940

Signalling, inter-exchange (Signalling System No. 7)
- Q.701 to Q.714, Q.761 to Q.766, Q.771 to Q.774

Speech encoding
- G.711, G.721, G.722, G.723, G.725

Supplementary services (I.250-series)
- Q.932
- Q.71 to Q.99
- X.2

Switching
- Q.500-series

Telephony, transmission quality
- G.100-series

Teleservices (I.240-series)
- E-series
- F-series
- X-series
- T-series
- U.201
- G.711, G.722

Terminals (I.470)
- T.90
- E.330, E.331
- P.31
- V.110, V.120, V.230

Tones and announcements (I.530)
- E.184
- V.25

Transmission
- G.700-series, G.800-series, G.900-series

Vocabulary (I.112, I.113)
- G.701

Biographies

Ian Dufour is Divisional Manager of Access Network Evolution in British Telecom UK's Network Headquarters. He started as a youth-in-training in 1962 and progressed 'through the ranks' on a variety of duties concerned with network planning, cable and transmission systems and the design of computer planning sytems. In his previous job, he steered through the conversion of the junction network to digital working by the widespread adoption of optical fibres, including the change to single-mode fibres. In his current job, he pioneered the use of optical fibres and electronics in the access network as well as introducing Blue Book standard ISDN. He is a European Engineer, a Chartered Engineer and a Member of the Institution of Electrical Engineers.

John Marshall is Head of Access Systems Engineering in British Telecom's Network Headquarters. He started his career in the Research Department, where he was involved in early investigations into high-reliability semiconductors used in deep-sea repeaters. Subsequently, he worked in Local Lines Division on wideband television distribution systems and was responsible for some of the early prototype VHF/UHF conversion units needed to serve customer premises. He has been responsible for a number of projects in the transmission area including remote testing (RATES), automatic loopback equipment (ALE) and the development of digital automatic cross-connect equipment (ACE) used in KiloStream service provision. He was promoted to his current position in 1988 and has since been responsible for system engineering activities within the access network. This has included project management responsibility for network co-ordination and implementation of ISDN basic- and primary-rate services. He has a B.Sc. degree from the City of London University and a Masters degree in Telecommunications Systems from the University of Essex. He is a Chartered Engineer and a Member of the Institution of Electrical Engineers.

Fred Welsby joined the British Post Office with a B.Sc. in Electronics in 1971, after which he spent 10 years on specification and approval of crossbar telephone exchanges. The next two years were devoted to managing the development of 30-channel pulse-code modulation signalling units, and the following one year engineering the infrastructure to install and maintain the computerised directory assistance system. In 1984, he established a unit to specify, validate and provide technical support of British Telecom's ISDN pilot (IDA) service. As Head of ISDN Network Engineering, he has overseen the development, launch and roll-out of the IDA service, of the primary-rate (Multi-line IDA) service and the development of the basic-rate (I.420) service. He is a Corporate Member of the Institution of Electrical Engineers.

A Multiplex Solution for Initial ISDN Provision

J. F. MARSHALL, and F. WELSBY†

Of the major telecommunications operators, British Telecom alone has opted for a multiplexer solution for initial provision of basic-rate ISDN service. This article reviews the technology necessary to provide digital services over the existing access network with particular reference to the multiplexer solution.

INTRODUCTION

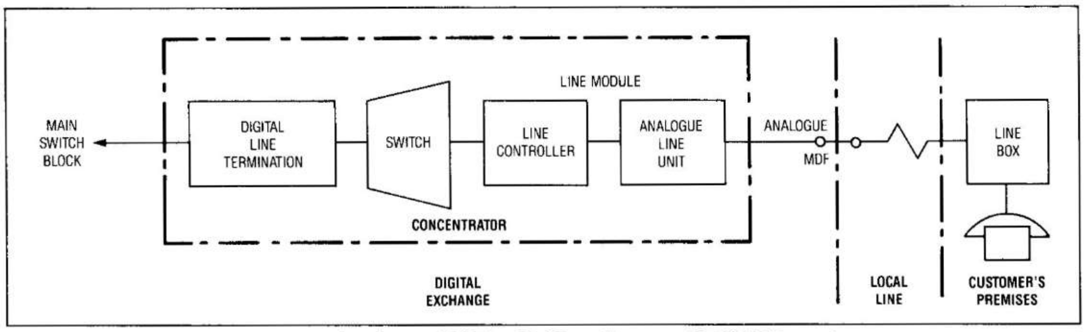
The preceding article[1] covered the background to the integrated services digital network (ISDN) and British Telecom's plans for its implementation on a national scale. Clearly, ISDN is not so much a product in itself, but a network-technology means of delivering a wide range of advanced communications facilities to meet customers' increasing service requirements. The key enabler is the integrated digital network (IDN). Only by harnessing, and where necessary enhancing, the advanced switching, signalling and transmission capabilities of the network can the required range and quality of services be ubiquitously delivered.

By definition, ISDN is not an overlay network. Its implementation in the UK has demanded co-ordinated developments in the existing switches, both System X and AXE10, and their associated management systems in the operations and maintenance centre. In addition, the most significant development activity has been in bringing the necessary digital delivery capability to the access network. This article addresses some of the constraints of the access network as an environment for digital signalling and transmission, and outlines the multiplexer solution implemented by British Telecom to overcome these constraints and meet the early need for an internationally-conformant basic-rate service, *ISDN 2*.

ACCESS NETWORK

A conventional telephone circuit is the product of many years of development. It has been optimised to carry signals within the frequency band 300 – 3400 Hz over distances of 5 km or more, limited principally by loop resistance. Where a customer is served by a digital exchange, the analogue-to-digital conversion is performed in the line module of the exchange. The basic-rate ISDN service must be introduced into this environment by using existing local line plant to reach the vast majority of existing and potential customers. British Telecom is employing multiplexers (IMUX) to provide the digital local access signalling and transmission capability. The reasons for this are discussed later; the impact on the access network is demonstrated in Figures 1 and 2.

Figure 1
Analogue line unit connection



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SDN 2 line network
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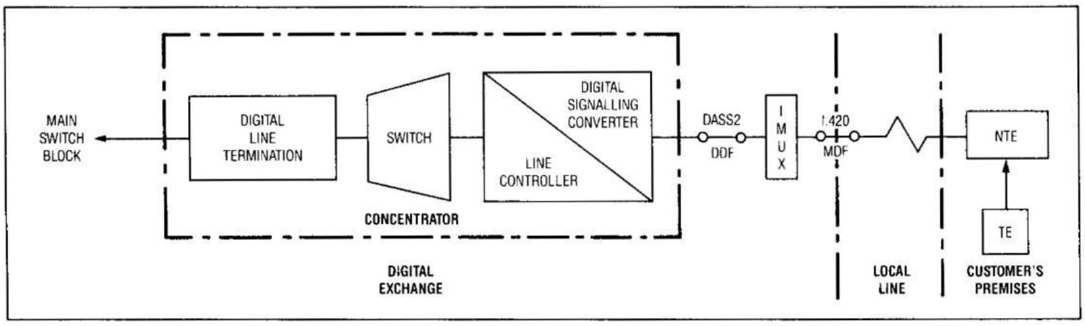

DDF: Digital distribution frame MDF: Main distribution frame NTE: Network terminating equipment
TE: Terminal equipment

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The functional requirements of a basic-rate ISDN service (such as ISDN 2) are defined by the CCITT in the series of recommendations based around Recommendation I.420[2]. These identify two 64 kbit/s channels for voice or data together with a separate 16 kbit/s channel to be used for signalling and (optionally) lower-speed (packet) data. The recommendations refer to the 64 kbit/s channels as *B-channels*, and the signalling channel as the *D-channel*, giving rise to the common term of *2B+D* to describe the interface. Thus the challenge for the access network is to transport 144 kbit/s of customer data using a medium intended to cater for a bandwidth of less than 4 kHz.

This additional capacity is achieved by the use of a digital transmission system terminating, on the one hand, at a line card in the digital exchange and, on the other, at the network terminating equipment (NTE) which replaces the telephony line box at the customer's premises (Figure 3). The powering of the NTE in addition to a telephone, which may be required for emergency calls in the absence of local power, makes the line-feeding requirements far more onerous than for telephony circuits. To fulfil the power requirements at the customer end and achieve the specified reach of the system, ISDN 2 lines must be fed at 90 V instead of the traditional 50 V.

Because of the high bit rate on the transmission system, it has been found that far-end and near-end crosstalk can be more significant than loop resistance in limiting the range of such a circuit. British Telecom's Integrated Digital Access (IDA) service[3,4], introduced in 1985, uses a burst-mode transmission system which time-shares the 2-wire medium to give duplex working at 80 kbit/s by using bursts of transmission at 256 kbit/s. This technology was available in the early part of the last decade and works well up to a range of about 3 km (depending on the gauge, and mix, of cable encountered). The specifications for the ISDN 2 service call for service on circuits some 50% longer. This is not feasible by using burst-mode technology, and it is generally accepted that echo-cancelling transmission systems are necessary to provide the capacity and reach for public basic-rate access. Such systems are complex but are now readily realisable in silicon and are, thus, economic. Above this basic transmission level, a further mechanism is invoked to limit the line baud-rate and, hence, improve the crosstalk performance; this translates data presented in binary format (two voltage levels) into a code using three (ternary) or even four (quaternary) discrete voltage levels. Nine combinations are available by using two digits of a ternary code and 16 are available by using two digits of a quaternary code representing, respectively, three and four digits of a binary code. British Telecom's current ISDN 2 implementation uses a 3B(inary)/2T(ernary) coding in a

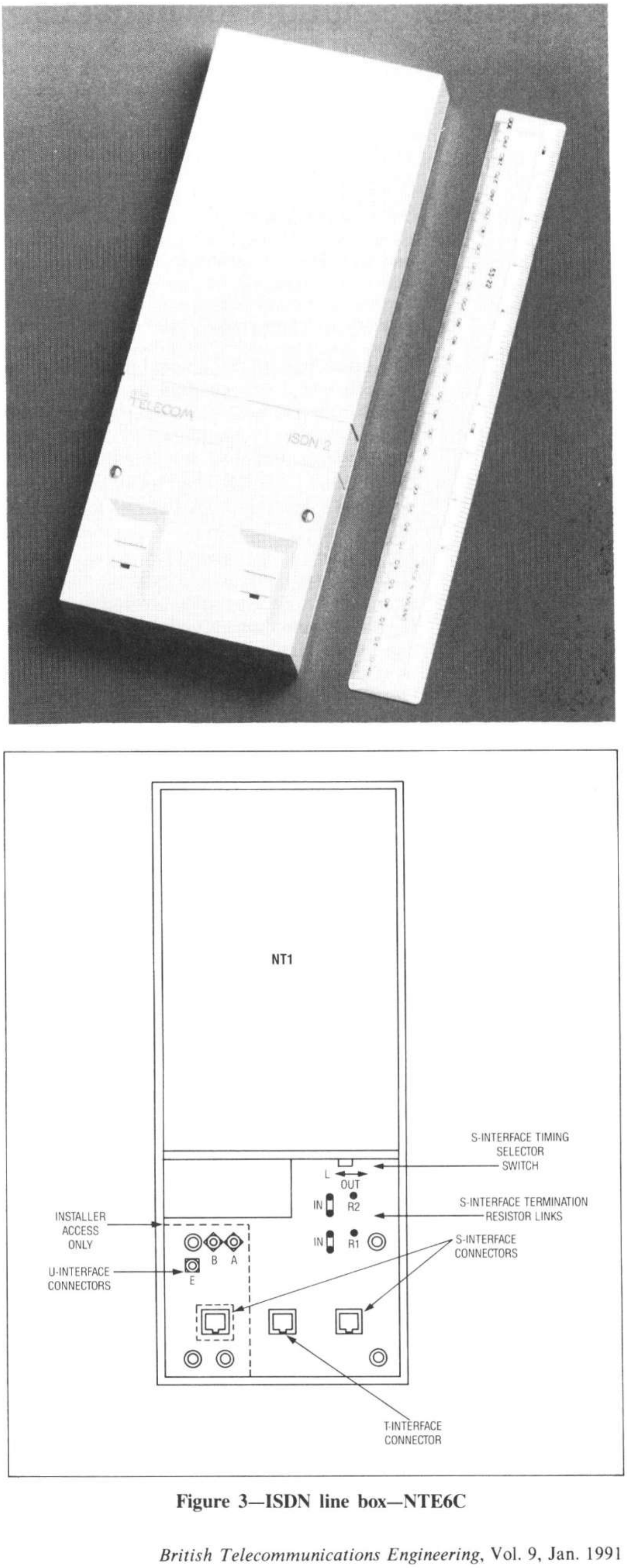


Figure 3—ISDN line box—NTE6C

108 kbaud transmission system. The coding system that appears to be emerging as a de facto standard, which was devised at the British Telecom Research Laboratory, Martlesham Heath, and adopted by the American National Standards Institute (ANSI) in the United States, uses a 2B/1Q coding scheme in an 80 kbaud transmission system. Both of these designs cater for a transport data rate of 160 kbit/s allowing 16 kbit/s for synchronisation and maintenance purposes over and above the 144 kbit/s of customer data.

SIGNALLING REQUIREMENTS

For normal telephony, the signalling requirements are quite simple: on-hook, off-hook, dialling (loop-disconnect pulse trains or in-band multi-frequency) and answer/meter cater for most calls. The provision of digital services over the local network brings demands on the signalling system beyond the capabilities of these in-band systems. For example, the call set-up message can carry user data (perhaps a password to log onto a remote computer system, or a personalised greeting to the recipient); the set-up message also carries terminal-compatibility information to ensure that only a suitable terminal will answer the call (for example, a Group 4 facsimile machine will not answer a telephony call). While one call is in progress, a second (independent) call can be established on the second channel and, during all of this time, the signalling channel could be carrying packet traffic directed to several destinations.

The 16 kbit/s D-channel shared by the two B-channels uses a protocol which has been designed to cater for this level and complexity of signalling. It is also available for packet access, but this is not allowed to interfere with the signalling since individual frames of information are prioritised with signalling frames being allocated higher priority than packet frames and, thus, handled first.

WHY THE MULTIPLEX SOLUTION?

It could be argued that the above digital delivery would most readily be realised as a digital local line termination on the switch (a line card) and, indeed, all the major switch manufacturers are now developing such equipment. However, British Telecom's experience with the IDA service demonstrated conclusively that manufacturers of customer premises equipment required stability of a user interface specification which commanded wide acceptance to warrant investment in terminal equipment for basic-rate ISDN. The CCITT recognised that the 1984 (*Red Book*) series of recommendations was not sufficiently advanced to provide this stability and targeted 1988 (*Blue Book*) for a more complete definition of the requirements.

It became apparent at an early stage that developments in switch technology to track these standards would compete for resources already designated for network modernisation. This would have impacted on both the modernisation and ISDN programmes, and so an alternative was sought. This alternative was readily to hand as a by-product from the IDA service for which the 2 Mbit/s common-channel Digital Access Signalling System No. 2 (DASS2) had been developed. Deployment of DASS2 ports on both System X and AXE10 switches in the network was already programmed as part of the modernisation exercise, and a version of this feature-rich message-based signalling system had been created to support ISDN facilities via remote multiplexers. The opportunity was available to develop a multiplexer which, because of its relatively compact software, could track the evolving standards more easily, and which could support the two B-channels from each of 15 customers on the 30 B-channels of a 2 Mbit/s bearer and map the CCITT Q.931 messages on the D-channels into DASS2 messages on timeslot 16. An additional, potential, benefit of the multiplexer solution was that of enabling remote service to be provided in locations not yet served by a digital local exchange.

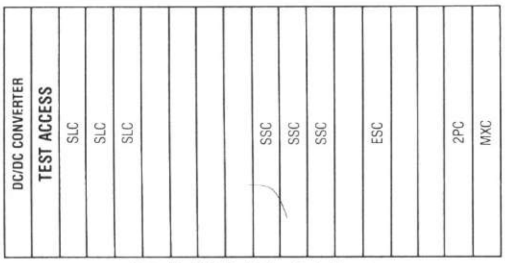
The use of a multiplexer does have some potential disadvantages. The extra stage of complexity adds cost to the service and complicates management and maintenance of the local loop. The use of the multiplexer involves an extra stage of mapping of the signalling protocols which now have to be mapped from I.451 via DASS2 to CCITT Signalling System No. 7 for inter-exchange working. Also, the connection of the first line on any exchange requires the installation and commissioning of a complete multiplexer rather than the fitting of a digital line card.

However, the balance of advantage during the early years of the service lies with the multiplexer as is evidenced by the testing that was carried out on the multiplexer in mid-1990 of all the facilities finalised by the European Telecommunications Standards Institute (ETSI) up to December 1989. It will be some time before the exchange systems can be enhanced to cope with some of the more esoteric cross-network facilities but, in due course, those facilities will be offered without significant change to the user interface being required.

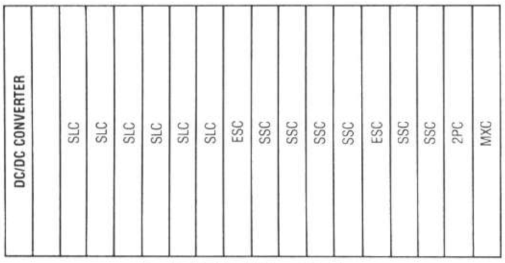
DESCRIPTION OF THE IMUX

The function of the IMUX is to multiplex the communications traffic associated with a number of ISDN 2 lines to one or more DASS2 ports on its parent digital exchange. Each DASS2 port can handle the traffic associated with up to 15 ISDN 2 lines (that is, thirty 64 kbit/s channels).

The IMUX is a variant of the PDMX developed and manufactured by STC. The multiplexer comprises a range of 8VU-height cards fitted into a TEP-1E shelf, which also contains a DC/DC converter. Two configurations of the

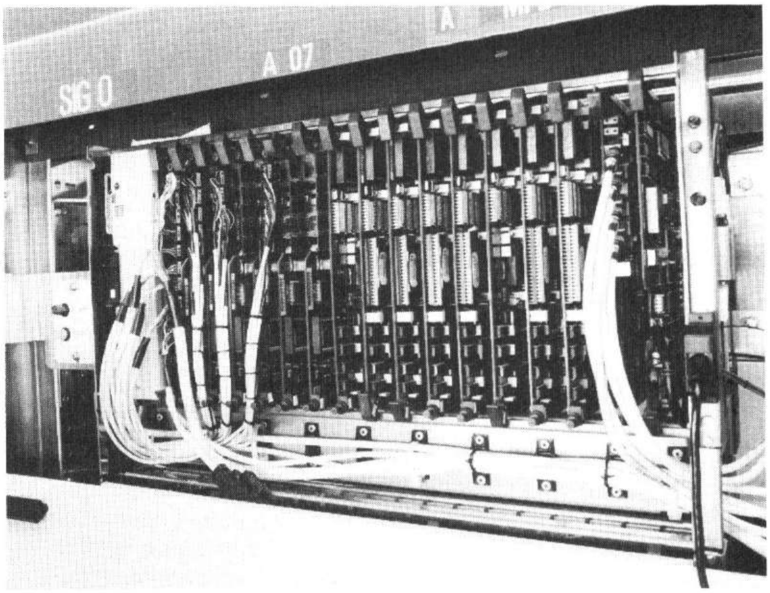


(*a*) IMUX 11A (15-line)



(*b*) IMUX 12A (30-line)

SLC: Subscriber line card
ESC: Exchange signalling card
SSC: Subscriber signalling card
2PC: Two-port card
MXC: Multiplexer control card



(*c*) IMUX 12A (30-line)

Figure 4—ISDN multiplexers—15-line (IMUX 11A) and 30-line (IMUX 12A)

cards in the shelf are shown in Figure 4. The network terminating equipment was developed in association with the IMUX.

Multiplexer Control Card (MXC)

The multiplexer control card (MXC) maintains overall control of the multiplexer. It controls the distribution of information from the hand-held terminal which is used for programming the tributary units during configuration (that is, by the manufacturer), and which can also be used for various maintenance activities. Each tributary card contains a bus interface device which receives control messages from the MXC and transmits alarm and status messages to the MXC.

The MXC receives all alarm messages whether from its own processor or from the tributary cards. The alarms are displayed on an alarm panel fitted at the end of the shelf; those directly affecting customer service, such as loss of synchronisation, high error rate or high or low line current, are also transmitted to the digital exchange through the DASS2 signalling system to alert the local-line fault reporting point. To cover a fault in the 2 Mbit/s connection to the digital exchange, it has been arranged that the MXC can also receive and process faults generated by an adjacent multiplexer.

Two-Port Card (2PC)

The two-port card (2PC) provides IN and OUT terminations for two 2 Mbit/s transmission systems connected to the digital exchange port by coaxial cable. Type 43 connectors are used. This card performs the multiplexing and demultiplexing functions of the system.

Two identical multiplexer circuits each multiplex and demultiplex thirty 64 kbit/s channels from the 15 customer lines into and from time-slots 1 − 15 and 17 − 31 of the 2 Mbit/s primary network data interface data frame format. The two channels allocated to a customer line are separated by 16 channels as shown in Table 1.

Packet service access on the D-channel is not currently offered on ISDN 2. However, to cater for the introduction of this service, the 2PC card can be configured to multiplex the incoming

TABLE 1
Allocation of 2 Mbit/s Channels to Customer Lines

Line	Channel A	Channel B
1	1	17
2	2	18
3	3	19
4	4	20
5	5	21
6	6	22
7	7	23
8	8	24
9	9	25
10	10	26
11	11	27
12	12	28
13	13	29
14	14	30
* 15	* 15	* 31

(* See text)

packets from the customers' D-channels onto one or both of time-slots 15 and 31 of the 2 Mbit/s bearer to the digital exchange. These time-slots could be passed through the exchange on semi-permanent connections to a packet handler for interfacing with the packet switch. The obvious overhead of such a configuration is that the multiplexer circuit can support only 14 customer lines.

The 2PC circuits also multiplex and demultiplex the DASS2 signalling protocol information between the exchange signalling cards and time-slot 16 of the 2 Mbit/s primary network interface data frame format.

Time-slot 0 is also terminated by the 2PC to monitor and generate transmission system alarms and to allow synchronisation of the two multiplexer circuits to the incoming datastream from link A. Should this synchronisation source fail, the card has an internal clock from which the multiplex circuits derive synchronisation until the preferred source is restored.

Early IMUXs deployed by British Telecom were configured to support only 15 ISDN 2 lines and used only one 2 Mbit/s port on the 2PC card (Figure 4 (*a*)). Fully equipped shelves comprising two complete multiplexers which fully utilise the capacity of the 2PC card are now the standard (Figure 4 (*b* and *c*)) and the earlier equipment has been upgraded to become sub-equipped 30-line shelves.

Exchange Signalling Card (ESC)

The exchange signalling card (ESC) provides the termination of the DASS2 signalling protocol and communicates with up to three subscriber signalling cards to provide the necessary call control to support up to 15 ISDN 2 customer lines using time-slot 16 of a single 2 Mbit/s network interface. The ESC also caters for two other high-level data-link control connections to the network carried over time-slots 15 and 31 of the network interface for D-channel packet access.

Subscriber Signalling Card (SSC)

Each subscriber signalling card (SSC) provides the logical termination of the D-channel and of the auxiliary maintenance channel for five ISDN 2 lines.

For each D-channel, signalling messages formatted in accordance with CCITT Recommendation I.451 carried on the customer's line via the subscriber line card are mapped in the SSC to and from the DASS2 Layer 3 messages required by the ESC. This mapping function is carried out on the SSCs to reduce the load on the ESC and enable it to meet the requirement for packet throughput when D-channel packet access is supported.

Information from the subscriber line card in the auxiliary maintenance channel is processed by the SSC and the results are passed as alarm and status messages to the multiplexer control card (MXC).

Subscriber Line Card (SLC)

Each subscriber line card (SLC) provides the physical connections for five ISDN 2 customer lines. Within the multiplexer, the SLC connects B-channel data to and from the 2PC card via data highways; D-channel and supervisory information to and from the SSC via data highways; and receives clocking and synchronisation signals from, and transmits alarm and status information to, the MXC. The flexibility of the IMUX design would allow any relationship between the notional line number, the internal multiplexer data highway time-slot allocation and the 2 Mbit/s channel allocation. However, to simplify installation and maintenance procedures, a fixed relationship has been adopted whereby SLC No. 1 is the left-most when viewed from the front of the shelf and carries lines 1–5; SLC No. 2, in the middle, carries lines 6–10; and SLC No. 3, on the right, carries lines 11–15. The 2 Mbit/s channel allocations for the lines are given in Table 1. Since SSCs also each cater for five customer lines, the SLCs and SSCs are 'paired' and the SSCs are numbered accordingly.

Each of the five similar transmission and power feed circuits on an SLC contains two custom large scale integration (LSI) chips—the analogue line transceiver chip and the digital signal processing chip—power feed and current-monitoring circuitry for the 2-wire line and over-voltage protection.

The circuitry on this card implements the echo-cancelling transmission system employing a 3B/2T line code which enables the service to be provided over existing local cables up to a transmission limit of 40 dB measured at 100 kHz.

Power is fed to line at a nominal 90 V to enable the customer-end termination of the transmission system (the NT1) to offer all its facilities over all customer lines up to 1100 Ω resistance. Existing local cable plant is used to carry this new service. The design of the DC/DC converter provides a floating supply which is insensitive to 2-wire line polarity. Foldback current limiting circuitry is implemented and abnormal line current (high or low) is signalled to the MXC and causes a fault report to be passed, via DASS2, to the digital exchange.

DESCRIPTION OF NTE6C

At the customer's premises, the NTE6C is the ISDN 2 equivalent of the telephony line box, albeit somewhat more conspicuous (Figure 3). It houses a Network Terminating Equipment Type 1 (NT1) in a screened enclosure to meet the latest electromagnetic compatibility regulations, and a supplementary card carrying line filtering and user configuration straps for the

S-bus. It mounts two standard basic-rate ISDN sockets for customer terminals and provides the option of concealed wiring entry at the rear for connection of the S-bus in the same manner as the telephony line box.

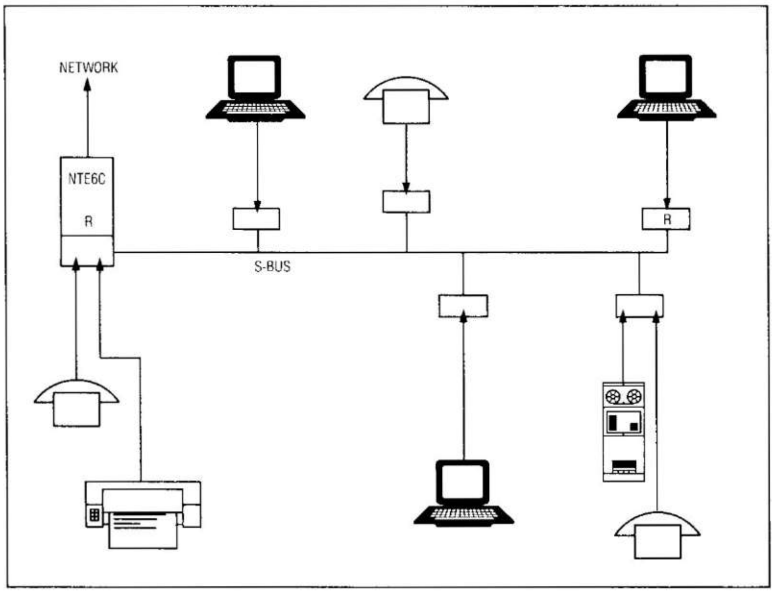
The function of the NT1 is to terminate the transmission systems and Layer 1 protocols from the network (frequently referred to as the *U-interface*) and the S-bus. On the network side, the termination is of the echo-cancelling digital transmission system implemented on the SLC in the multiplexer, and the same two VLSI chips are employed. The NT1/SLC combination allows 144 kbit/s of customer data and signalling together with auxiliary information relating to maintenance, supervision and control of the transmission system to be carried over a single pair in the local network.

The customer side of the NT1, the *T-interface*, forms the regulatory boundary of the network in the UK and most European countries. The functionality of this interface is clearly specified in the CCITT I-series recommendations[2] and refined in ETSI specifications. To support this functionality, a second digital transmission system, operating at 192 kbit/s, is implemented in the NT1 to permit transport of 144 kbit/s of customer data and signalling from terminals together with the Layer 1 S-interface protocol and framing.

A further function of the NT1 is to transfer 'emergency' power from the network sufficient for one telephony terminal connected to the S-bus to function in the event of a local mains power failure at the customer's premises. A designated terminal is permitted to draw up to 380 mW from the network in these circumstances.

DESCRIPTION OF S-BUS

The international standards for the ISDN basic-rate customer interface require a variety of terminal configurations to be supported. These configurations range from a single terminal at a distance of up to 1000 m from the NT1 (*point-to-point*) to eight terminals connected in parallel to a passive bus (the *S-bus*) of up to 200 m in length (*point-to-multipoint*). (Figure 5.) Where the receiving customer has installed a multipoint terminal configuration, the protocol allows for a sub-address to be included in the SETUP message to direct the call to a particular terminal. In addition, the SETUP message contains various elements to enable the receiving terminals to perform compatibility checking before attempting to answer the call; thus a voice call would be answered by a telephone and not by a Group 4 facsimile machine and vice versa. If the SETUP message does not contain a sub-address, or the terminals do not support sub-addressing, then all compatible terminals will attempt to respond to the incoming call; the NTE6C accepts the first response received and the other compatible terminals release.



Note: R denotes location of 100 Ω terminating resistors across transmit and receive pairs

Figure 5—Typical S-bus connections

FUTURE DEVELOPMENTS

Digital switch manufacturers are developing both basic-rate and primary-rate interfaces to the latest specifications and these will be introduced into British Telecom's network at the appropriate time. While the I.421, primary-rate, Recommendation does not currently include the additional protocols necessary to support network-based multiplexers, it is anticipated that such a superset will be created. Conversion of the IMUXs in the network from the British Telecom designed DASS2 to the Q.931 protocols of I.421 will be essential to ensure uniformity of features and facilities for all basic-rate and primary-rate customers. Beyond this, the progressive evolution to higher bit-rate services (for example, 384 kbit/s) and, eventually, broadband ISDN is being studied.

CONCLUSION

Basic-rate ISDN is now positioned for national deployment under the ISDN 2 service banner. A major enabler in achieving the objective has been the deployment of a multiplexer solution to provide the digital delivery over the existing access network copper plant. This has maximised utilisation of existing DASS2 interfaces on the digital exchanges and largely divorced the major developments necessary in access network equipment from the digital exchange programme while providing a stable internationally-compliant customer interface against which developers of customer premises equipment could move ahead with confidence.

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Biographies

John Marshall is Head of Access Systems Engineering in British Telecom's Network Headquarters. He started his career in the Research Department, where he was involved in early investigations into high-reliability semiconductors used in deep-sea repeaters. Subsequently, he worked in Local Lines Division on wideband television distribution systems and was responsible for some of the early prototype VHF/UHF conversion units needed to serve customer premises. He has been responsible for a number of projects in the transmission area including remote testing (RATES), automatic loopback equipment (ALE) and the development of digital automatic cross-connect equipment (ACE) used in KiloStream service provision. He was promoted to his current position in 1988 and has since been responsible for system engineering activities within the access network. This has included project management responsibility for network co-ordination and implementation of ISDN basic- and primary-rate services. He has a B.Sc. degree from the City of London University and a Masters degree in Telecommunications Systems from the University of Essex. He is a Chartered Engineer and a Member of the Institution of Electrical Engineers.

Fred Welsby joined the British Post Office with a B.Sc. in Electronics in 1971, after which he spent 10 years on specification and approval of crossbar telephone exchanges. The next two years were devoted to managing the development of 30-channel pulse-code modulation signalling units, followed by a year engineering the infrastructure to install and maintain the computerised directory assistance system. In 1984, he established a unit to specify, validate and provide technical support to British Telecom's ISDN pilot (IDA) service. As Head of ISDN Network Engineering, he has overseen the development, launch and roll-out of the IDA service, of the primary-rate (Multi-line IDA) service and the development of the basic-rate (I.420) service. He is a Chartered Engineer and a Member of the Institution of Electrical Engineers.

Telecommunications Engineering Staff College

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Today's fast-changing telecommunications business has created a need to select and train a body of senior engineering professionals to the highest standard. To meet this need, British Telecom has created the Telecommunications Engineering Staff College, whose first Masters programme commenced in November 1990. This article outlines the concepts of the course and reviews its nine-month programme, which is of high academic level and which covers all aspects of decision making in a world-class Telco business.

INTRODUCTION

Over the last decade, telecommunications has dramatically changed from relatively simple technology in a monopolistic era to a fast-changing environment of demanding business requirements. The key changes are expanding and sophisticated market needs, rapid technological development, increasing competition, globalisation and tougher regulation. Additionally, the telecommunications business is characterised by its capital intensiveness and related network operating costs which are heavily influenced by engineering decisions (Figure 1).

These changes have a profound effect on BT engineering managers, who must not only have a thorough understanding of the business dimension of engineering, but also possess the capability of anticipating and interpreting customer requirements in network terms. This means that they must understand macro-economic trends, and have a comprehensive knowledge of telecommunications networks as well as a sound appreciation of engineering technology, its application and management. They must also possess the vision and the capability to stimulate innovation and persuasively articulate the benefits of engineering solutions to meet business needs.

It is therefore vital, if BT is to become the top world-class Telco, to improve the engineering competence of the company by a rigorous selection of senior managers combined with appropriate preparation through training and education.

A new approach is required to the education of engineering managers because these needs cannot effectively be met by universities and business schools. BT has therefore created the Telecommunications Engineering Staff College whose mission is to become a world-class centre of engineering education that will create the cadre of high-calibre senior professional engineers necessary to meet its future aspirations. It will become an internationally recognised centre of excellence, being attractive to high-calibre engineers and enhancing BT technical reputation at home and overseas. Above all, the intention is to develop a body of the highest-calibre managers and leaders.

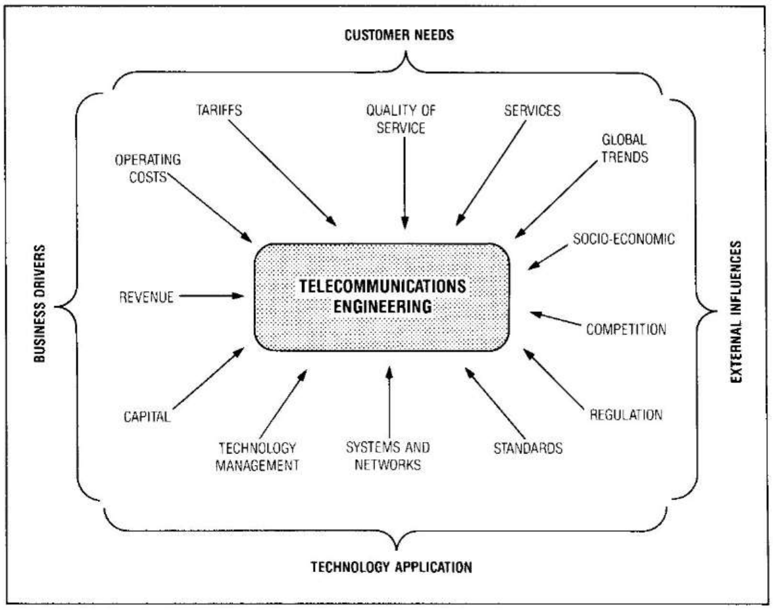

Figure 1
Engineering influences

CONCEPTS

The Staff College will run a nine-month programme, at Masters level, which is carefully structured to meet the needs of mature, senior and experienced engineers by an appropriate balance of theory and practice. Negotiations are being carried out with universities to obtain accreditation of the programme for the award of a Masters degree. The breadth of coverage with the necessary intellectual depth is achieved by using recognised subject-matter experts from BT, academia and industry in the UK and overseas. The visiting faculty comprises over 100 visiting lecturers. Delegates will be required to meet the standards applicable to a Masters degree with continuous assessment by projects, examination and dissertation.

Although engineering based, the Masters programme emphasises the business and operational dimensions plus the application of technology to satisfy customer needs in a privatised, competitive and regulated environment. This is achieved by

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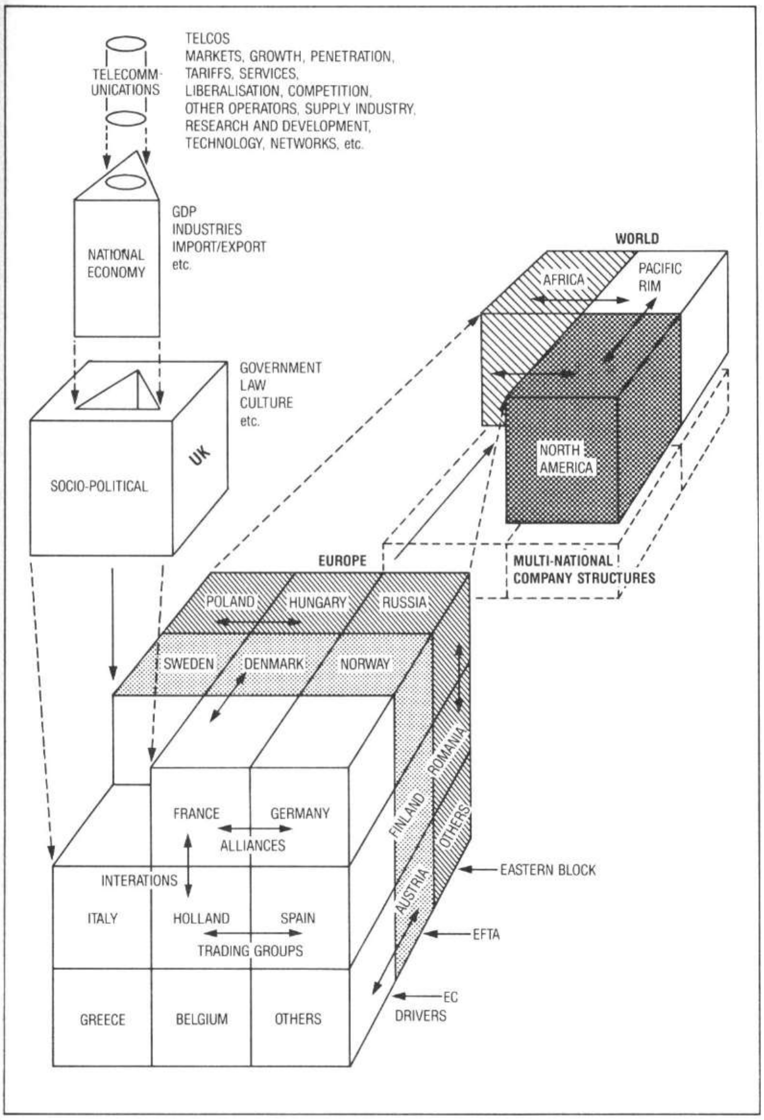


Figure 2—Global telecommunications relationships

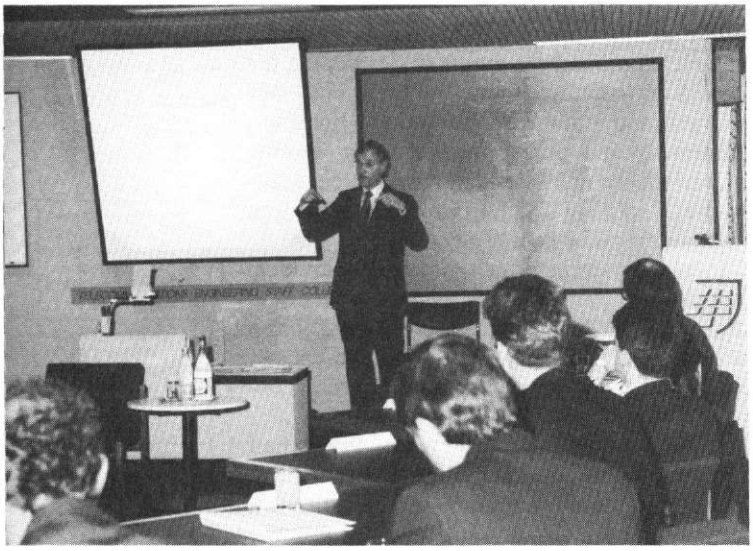


Figure 3—Dr. Alan Rudge, BT's Managing Director, Development and Procurement, discusses an issue with delegates

reinforcing theoretical lectures by case studies presented by practising managers working in the subject area being considered, together with exercises that stress the practical applications, business implications and customer connotations.

Particular importance is placed on understanding the macro-economic and global dimensions of telecommunications. Delegates will spend time in Europe and North America studying aspects of telecommunications such as global market trends and the relationship to national policy and global economics; the impact of the European Community from 1992; the requirements of multi-national companies, together with network developments and the best practices of other Telcos. Figure 2 illustrates the type of relationships that will be explored.

In addition to personal projects that will require individual delegates to visit various Telcos, the programme will be held at a number of overseas universities and educational establishments. Two are in France: L'École Nationale Supérieure des Télécommunications de Bretagne, a premium university in Brittany, and the Theseus Institute, a business college located near Nice. In order to promote a greater empathy with the European dimension and to prepare for 1992, delegates will be required to learn a European language to good conversational proficiency, which will be examined.

In North America, the delegates will visit The University of Southern California, the American Graduate School of International Management in Phoenix and the AT&T Corporate Education Centre, New Jersey.

Computing literacy is considered important not only to provide an insight of how computing can be used to improve the effectiveness and efficiency of BT's operations, but also to understand the impact of information technology on customer requirements. Delegates are provided with a lap-top personal computer before attending the course, with exercises to familiarise themselves with the most useful applications such as graphics, word processing and spreadsheets. The Telco business simulation and many other personal and syndicate projects are computer based. For example, a major loop exercise carried out in Bristol will require extensive use of line plant graphics. Additionally, computing, information engineering, software engineering and the influence of information technology on company operations are all important elements of the syllabus.

An important ingredient for creating top engineering managers is an understanding of the strategic thinking of the leading figures in the telecommunication industry. This is catered for by the weekly *heavyweight* speaker slot. A top leader from BT or the industry (UK and overseas) gives a short talk on a particular topic. But the real value lies in the ensuing debate which is designed to probe the major issues affecting BT (see Figure 3).

A major objective of the Staff College is to improve the ability of engineers to present engineering-based business cases to high-level management boards in a concise, jargon-free and persuasive manner. A *learning by experience* technique has been adopted whereby delegates are required, throughout the programme, to present the results of the various projects to panels of senior managers. These visiting panels ask penetrating questions typical of a board environment. Delegates are required to produce high-quality overhead-projector slides by using their lap-top graphics package. A media expert is available to assist in the development of presentations and subsequent critiquing of the performances from video recordings.

It is essential that senior engineering managers have a good appreciation of the field implications of their decisions, which are usually crucial to the success of implementation. In addition to being trained in some of the more important field skills, such as optical-fibre jointing, delegates will be required to undertake hands-on exercises involving exchange and transmission equipment. A substantial period of the programme will be spent at the BT Technical Training College, Stone, one of the world's best-equipped practical telecommunications laboratories. Extensive use will be made of the captive telephone exchanges, repeater stations and other examples of equipment deployed in the field. Delegates will also carry out a number of assignments each of one week duration, in the field.

It is not the intention of the Staff College to produce BT clones. The philosophy is to broaden horizons, promote enquiring minds and encourage creative thinking by allowing delegates to practise their decision making and other management and leadership skills in non-BT environments. This is accelerated by exposing them to overseas Telcos and educational establishments, using a balance of BT and non-BT lecturers and providing challenging assignments. For example, one such assignment places delegates in the shoes of major customers: another is a business tendering simulation that requires them to play the role of a telecommunications supplier.

SYLLABUS

The syllabus is structured in hierarchical form, building as a logical progression of modules from a technology base through to the use of technology to construct the various network elements of switching, signalling and transmission. This leads on to show how the various elements are interlinked to form networks together with the terminal equipment necessary to provide access and the customer services required. Higher levels in the syllabus hierarchy deal with the economic and performance dynamics of networks, network management and thence the processes and support systems necessary to plan, operate and maintain networks. The top-level module involves running a Telco business.

Orthogonal to and spanning these major layers in the syllabus are modules relating to the market; finance; the environment of regulation, competition, relationships to the economy of a country and the socio-political drivers. Finally, there are the all-pervasive standards that surround telecommunications today. Figure 4 illustrates how the modules in the hierarchy combine to provide the necessary comprehensive understanding of the telecommunications business.

STRUCTURE OF PROGRAMME

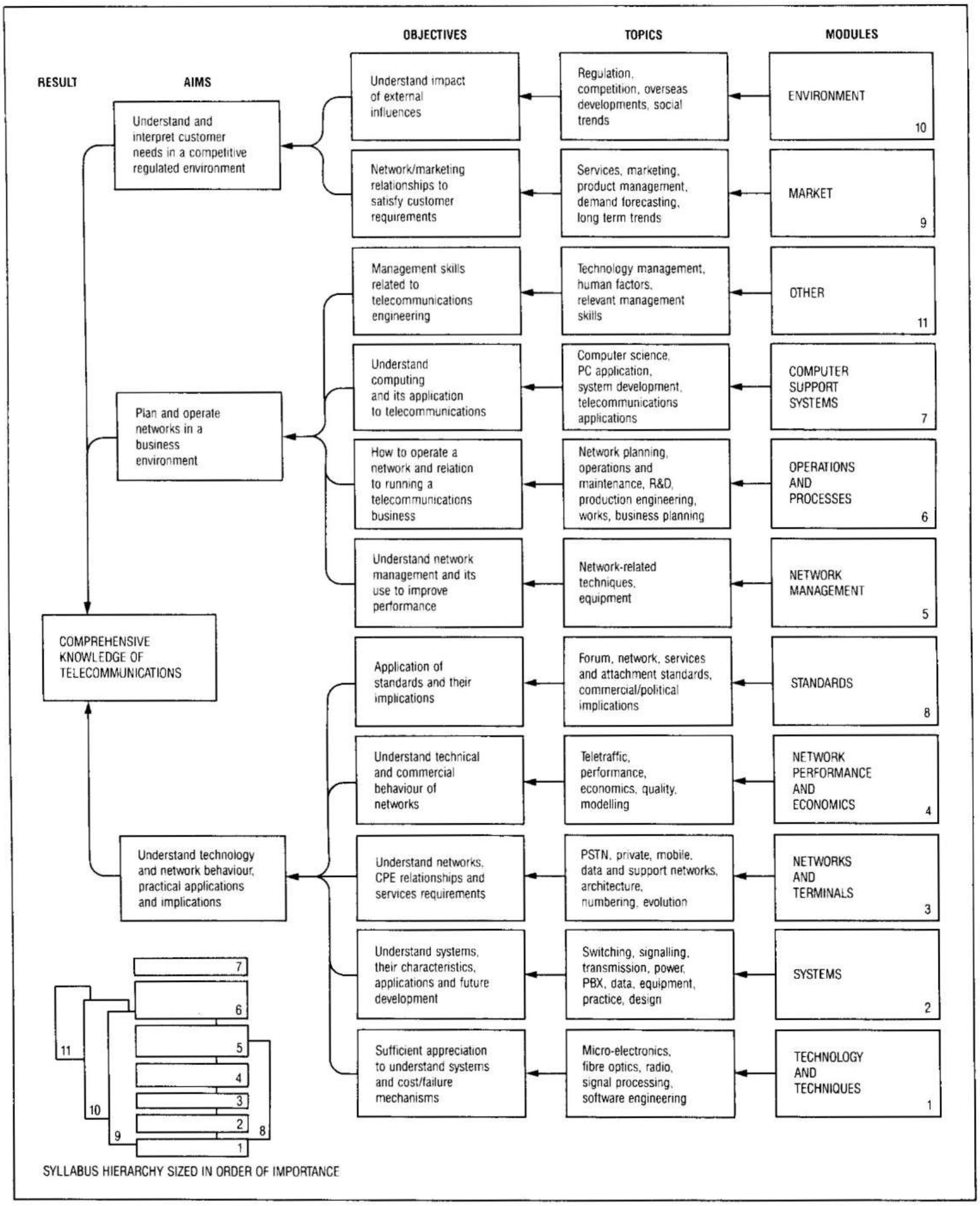
The programme is structured in three stages, each of three months duration. Delegates must attend all three stages, but these can be spread over, say, two years, should their release for a continuous nine-month period cause difficulties. Each stage is therefore self-contained, but builds on the knowledge gained from the previous one. The first stage has been designed to provide an overall appreciation of all the dimensions of telecommunications. The second stage builds on the first, but deals with the subject matter in more detail, while stage 3 pulls all the material together in the context of running a Telco business.

Great care has been taken to ensure that the programme sequence is logical and progressively builds towards completing the telecommunication jigsaw. The broad structure is shown in Figure 5. Each week has a theme and the philosophy is that the early part sets the culture of the programme by concentrating on the major business dimensions of telecommunications such as the market, finance and business planning. The engineering aspects are then dealt with, building from the technology and how it is used to create the various networks systems, thence to the network and the end-to-end system engineering embracing customer premises equipment, network behaviour, and, finally, the planning and operational aspects.

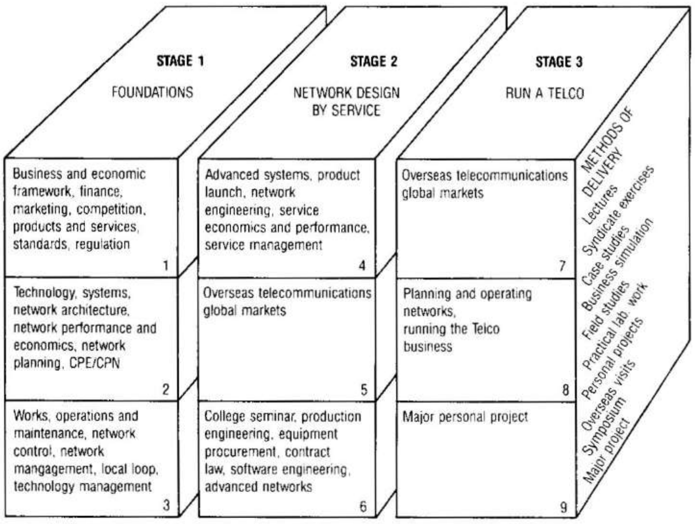
The second stage of the programme has been constructed around the theme of developing the network to meet the needs of new customer services, and embraces marketing, financial, engineering and procurement aspects. During this period, the delegates will spend three weeks on the Continent of Europe, and a college symposium will be held. The college symposium is a two-day event which requires individual delegates to submit original papers (which will be issued as symposium proceedings) on a common theme to be debated by an audience of senior managers, much like an external conference.

The final stage includes three and a half weeks in North America, a period at British Telecom Research Laboratories, Martlesham Heath, studying future developments and the study of running a Telco in a regulated, competitive environment. During this stage, four

Figure 4
Syllabus structure



RESULT
AIMS
OBJECTIVES
TOPICS
MODULES
Understand and interpret customer needs in a competitive regulated environment
Plan and operate networks in a business environment
Understand technology and network behaviour, practical applications and implications
COMPREHENSIVE KNOWLEDGE OF TELECOMMUNICATIONS
Understand impact of external influences
Network/marketing relationships to satisfy customer requirements
Management skills related to telecommunications engineering
Understand computing and its application to telecommunications
How to operate a network and relation to running a telecommunications business
Understand network management and its use to improve performance
Application of standards and their implications
Understand technical and commercial behaviour of networks
Understand networks, CPE relationships and services requirements
Understand systems, their characteristics, applications and future development
Sufficient appreciation to understand systems and cost/failure mechanisms
Regulation, competition, overseas developments, social trends
Services, marketing, product management, demand forecasting, long term trends
Technology management, human factors, relevant management skills
Computer science, PC application, system development, telecommunications applications
Network planning, operations and maintenance, R&D, production engineering, works, business planning
Network-related techniques, equipment
Forum, network, services and attachment standards, commercial/political implications
Teletraffic, performance, economics, quality, modelling
PSTN, private, mobile, data and support networks, architecture, numbering, evolution
Switching, signalling, transmission, power, PBX, data, equipment, practice, design
Micro-electronics, fibre optics, radio, signal processing, software engineering
ENVIRONMENT 10
MARKET 9
OTHER 11
COMPUTER SUPPORT SYSTEMS 7
OPERATIONS AND PROCESSES 6
NETWORK MANAGEMENT 5
STANDARDS 8
NETWORK PERFORMANCE AND ECONOMICS 4
NETWORKS AND TERMINALS 3
SYSTEMS 2
TECHNOLOGY AND TECHNIQUES 1
7
6
11
5
4
3
10
2
8
9
1
SYLLABUS HIERARCHY SIZED IN ORDER OF IMPORTANCE



STAGE 1
FOUNDATIONS
STAGE 2
NETWORK DESIGN BY SERVICE
STAGE 3
RUN A TELCO
Business and economic framework, finance, marketing, competition, products and services, standards, regulation
1
Technology, systems, network architecture, network performance and economics, network planning, CPE/CPN
2
Works, operations and maintenance, network control, network mangagement, local loop, technology management
3
Advanced systems, product launch, network engineering, service economics and performance, service management
4
Overseas telecommunications global markets
5
College seminar, production engineering, equipment procurement, contract law, software engineering, advanced networks
6
Overseas telecommunications global markets
7
Planning and operating networks, running the Telco business
8
Major personal project
9
METHODS OF DELIVERY
Lectures
Syndicate exercises
Case studies
Business simulation
Field studies
Practical lab. work
Personal projects
Overseas visits
Symposium
Major project

Figure 5—Timetable framework for 9 month Masters programme

weeks will be dedicated to the preparation of the dissertation for which a further three months will be allowed after the finish of the programme for the final polishing.

Care is taken to ensure that individual sessions are logically sequenced in connection to related topics. Figure 6 illustrates how sequence charts are used in the development of the programme.

Running through the whole of the programme are a number of *threads* which are common to most of the topics. For example, a most important one is the financial thread. Almost every subject has implications on the financial health of the BT business, expressed in terms of the company accounts. Therefore, for a number of topics, delegates will be required to assess the likely impact on the 'bottom line' and determine those aspects that contribute most to the financial sensitivity, using a broad-brush computer model of the business. Figure 7 illustrates typical examples of the application of this *financial thread*. Other important threads, shown in Figure 8, are concerned with the customer implications, the influence of standards, the application of theory to running the Telco business using the *Telco Business Simulation*, the relationship to the economy, the management of technology and 'board' presentational skills.

The computer-based Telco Business Simulation runs throughout the programme. It is based around a hypothetical Telco, known as *Brilliant Telecom* in the hypothetical island of *Utopia* (see Figure 9). The island is described in terms of its geography, and it is contoured to allow for computer-based planning of physical transmission links including microwave radio links. Figure 10 illustrates the use of the computer support system for planning radio links on Utopia. The information about the island also includes the socio-economic trends. Utopia already has a basic analogue network which needs modernisation to cater for the rapid growth and sophisticated services arising from the buoyant economy.

At appropriate times throughout the programme, delegates will be required to apply their knowledge to reasonably realistic Telco situations, but, because the simulation is tightly coupled to the timetable, the simulation is allowed to develop progressively right through the programme. It starts with the flotation of the Telco and determination of a business strategy; then it brings in the production of sector and

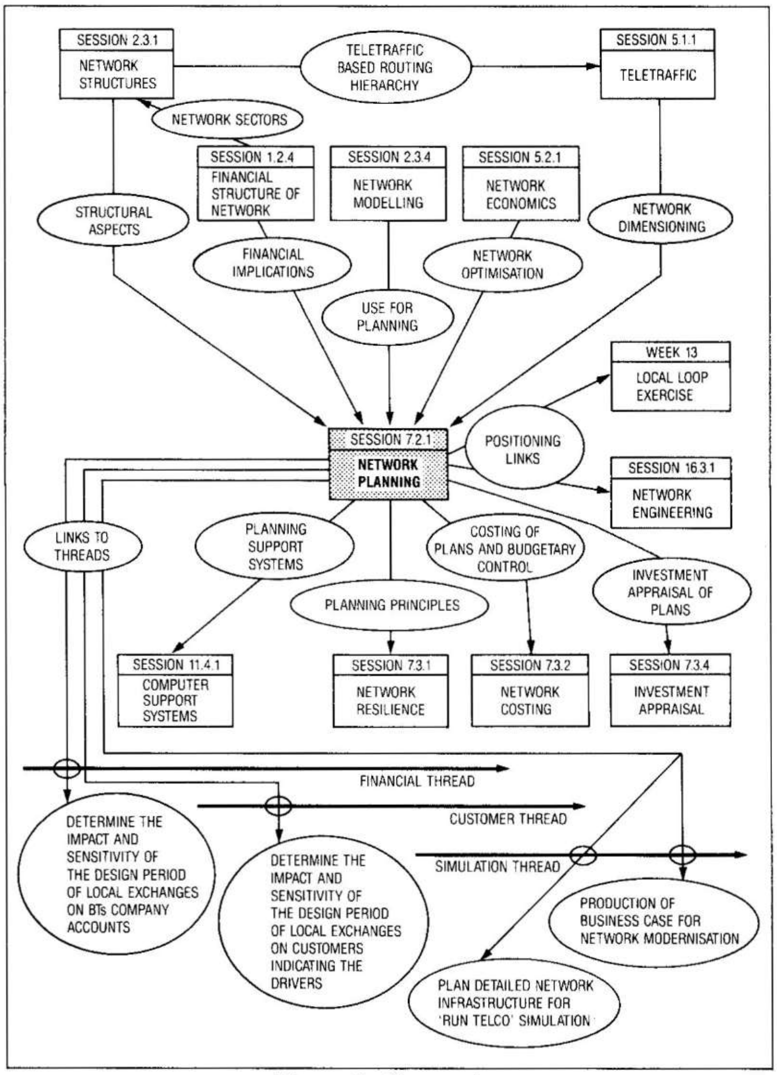


Figure 6—Sequencing

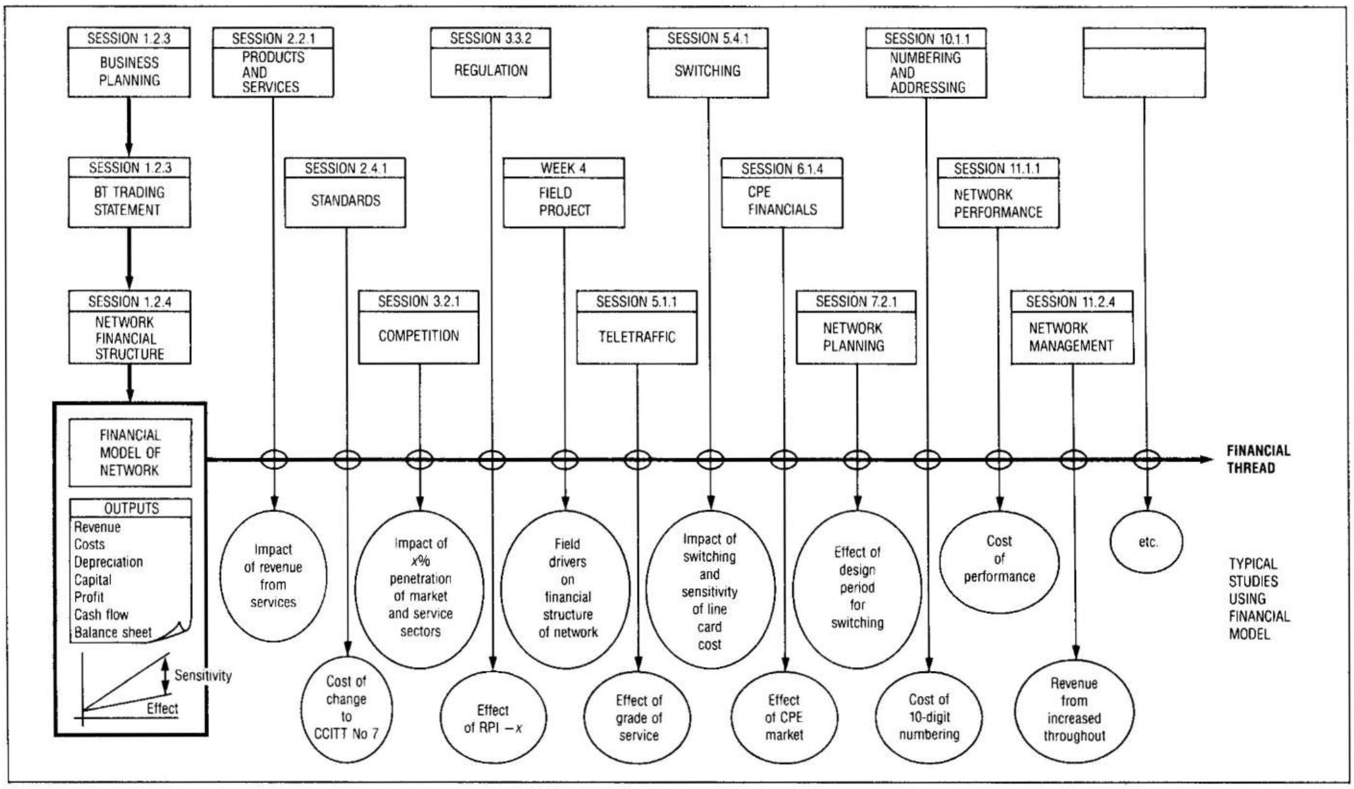


Figure 7—Financial thread

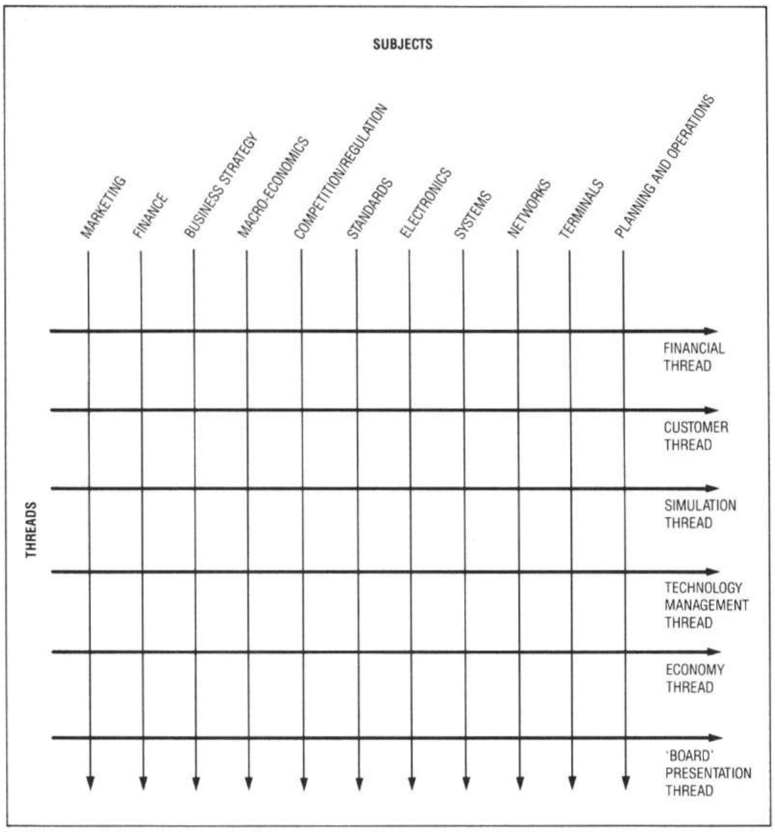


Figure 8—Threads matrix

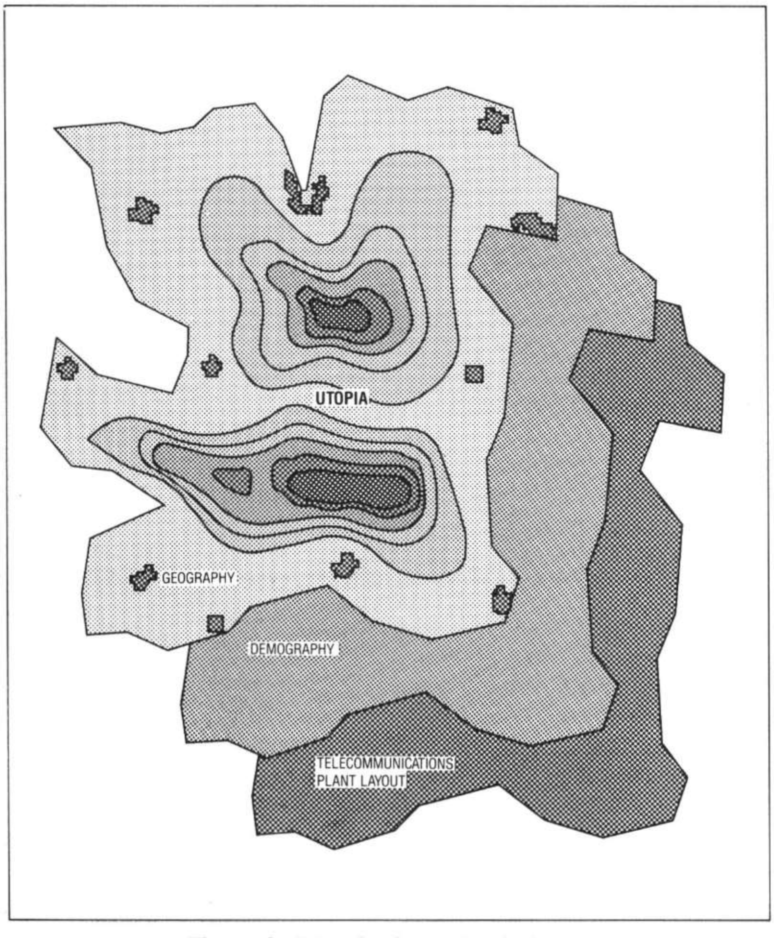


Figure 9—Telco business simulation

product forecasts and their conversion to network requirements; then network planning and modernisation; then the launch of a new network service. Procurement of equipment to build the network and the running of the Telco, as a classical business game in a competitive and regulated environment, is also covered. The Telco business simulation has been specially developed for the Masters programme and is probably the most comprehensive telecommunication business game in the world. Its use as a major thread in the Masters programme is illustrated in more detail in Figure 11.

One unique element of the simulation is the *tender exercise* run in conjunction with GEC Plessey Telecommunications Ltd (GPT). It is designed to improve the understanding of the supply industry. The delegates, in syndicates, are given an invitation to tender for the supply of a local exchange processor unit with remote concentrators. This also requires software development to provide a new service. Delegates are required to convert traffic data into hardware requirements; visit the GPT Liverpool factory to schedule production and determine the various costs of components, production, shipping, installation and testing, factory overheads, etc., determine the cost and time-scale for software development and how the costs are to be recovered; and produce a project management plan. Delegates are also required to justify the 'bid' price, in commercial terms, to a mock board of GPT managers and submit tenders to meet a tight deadline. They have to present their tender to an adjudication panel of senior BT managers who make awards based on the usual criteria of price, compliance, delivery etc. However, the winning syndicate is judged not only on the merits of their bid but, also, on the commercial implications for the supplier.

MANAGEMENT OF THE COLLEGE

The overall control of the college for the maintenance of high academic standards and the selection and assessment of candidates is exercised by a Governing Board chaired by Dr. Alan Rudge, BT's Managing Director, Development and Procurement. In addition to the Governing Board, an Advisory Council chaired by Dr. David Leakey (BT's Chief Scientist) advises on the detailed syllabus, its intellectual depth and its updating to reflect ongoing development. Day-to-day running of the college is the responsibility of the Dean of Studies and a small permanent college faculty. The lecturers will be drawn from a network of acknowledged subject matter experts from BT, industry and academia, both in UK and overseas.

Creating the cadre of senior engineering managers is an important feature of the college. To foster and maintain this, graduates become Honorary Fellows of the Staff College, meeting regularly to receive updated information and to

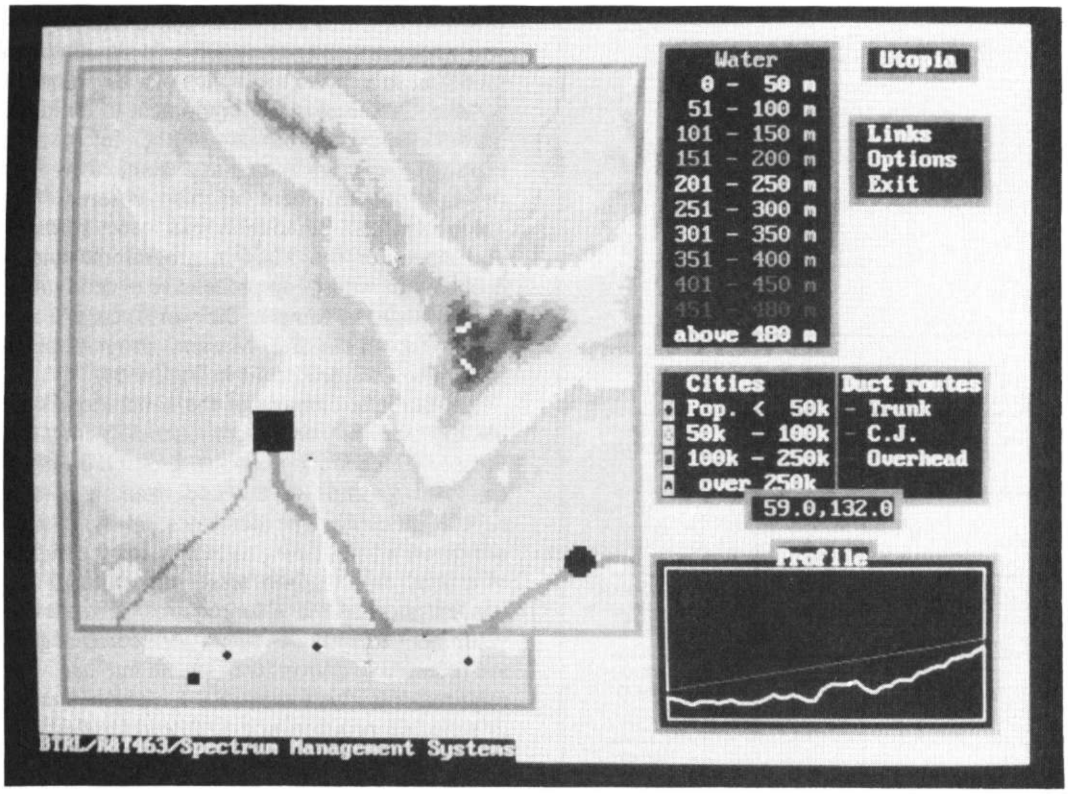


Figure 10
Computer support system for radio link planning showing path profile

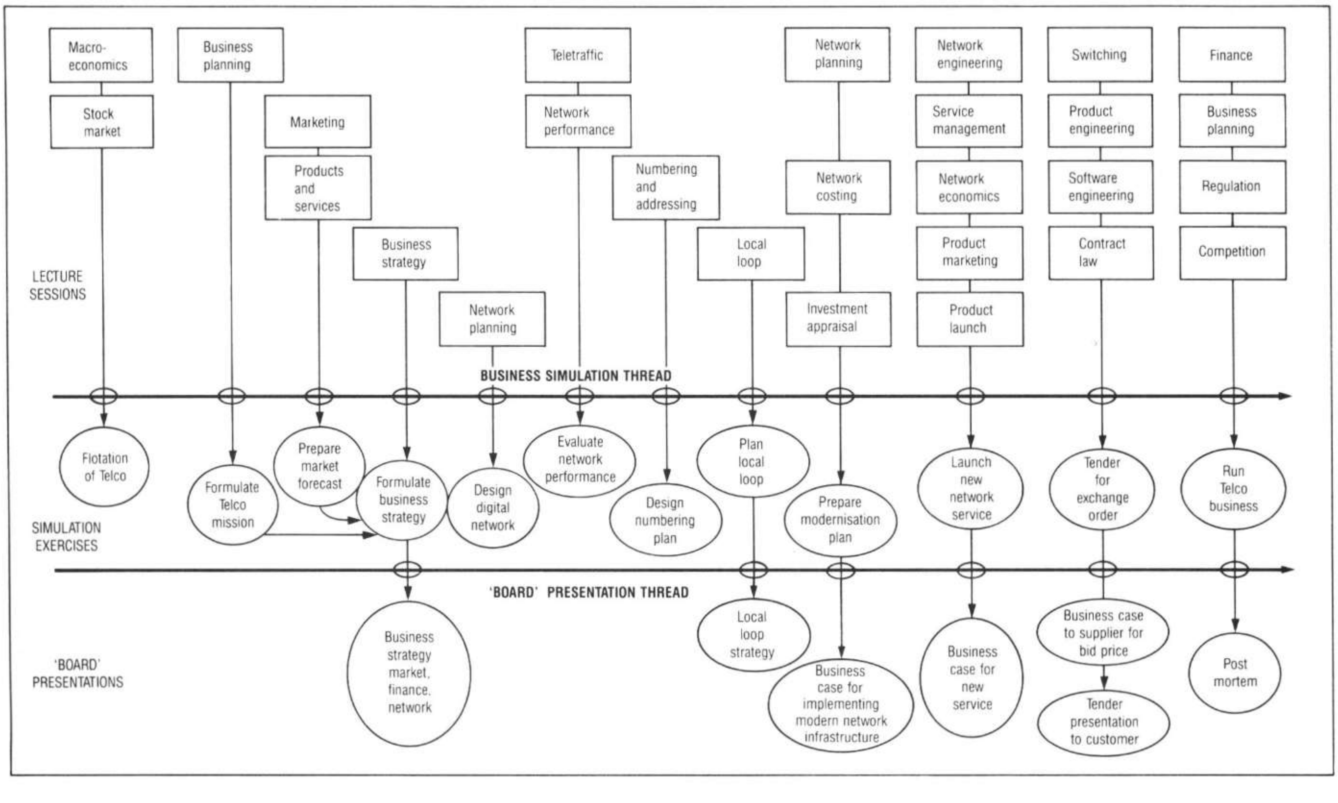
carry out practical exercises of benefit to BT and the Staff College.

PILOT COURSE

A two-month pilot programme was held during February and March 1990 (Figure 12). The objectives were to assist development of the full Masters Programme by providing an evaluation of the coverage and balance of material, methods of presentation, potential venues and collaborating universities. Additionally, the pilot programme aimed to provide the 15 senior engineers who participated with a rounded, up-to-date knowledge of telecommunications to improve their effectiveness as managers.

Over 100 visiting presenters were used on the pilot, from BT, universities and industry. These

Figure 11
Business simulation thread



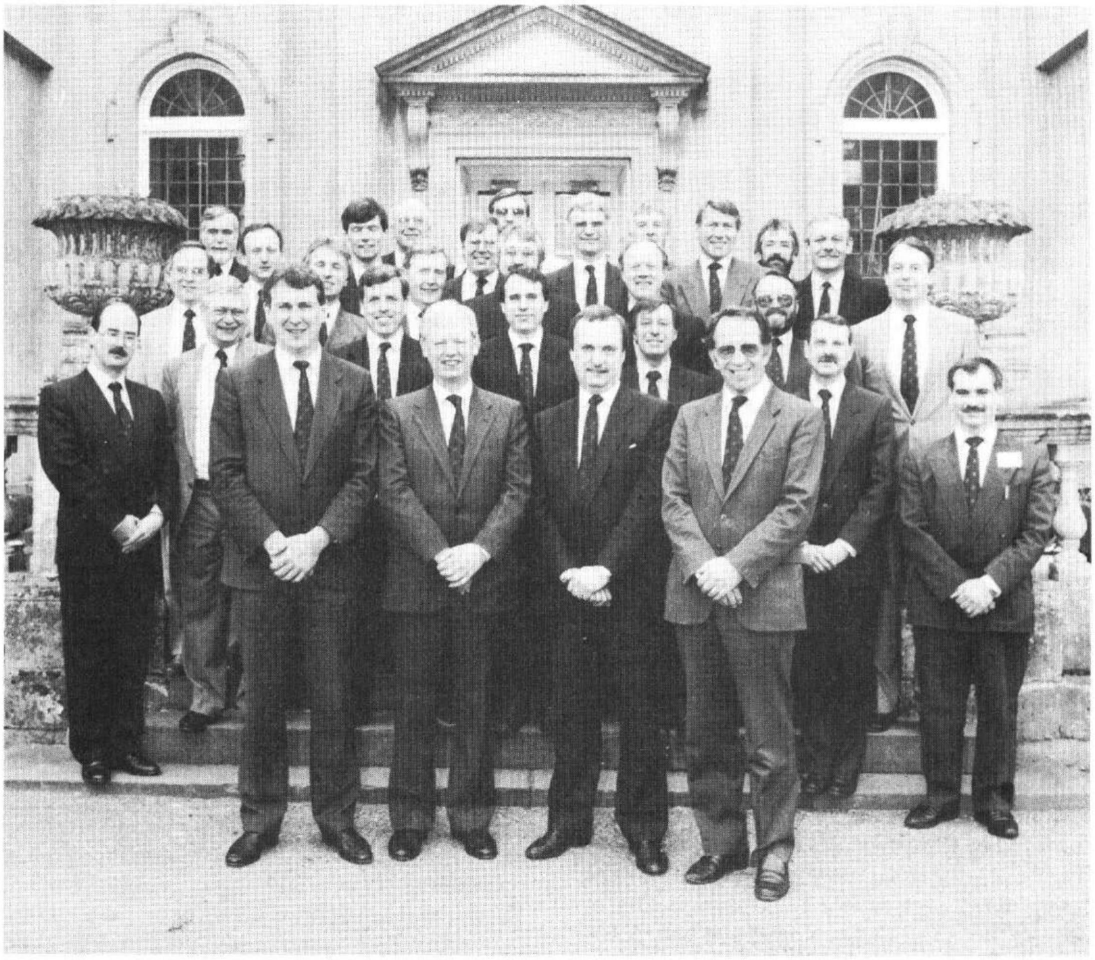


Figure 12—The Faculty and Fellows of the pilot programme at Bailbrook College with the present and past Directors of Network, Chris Earnshaw and John Tippler

included subject experts, practising managers, panellists and 'heavyweight' speakers. Valuable feedback was obtained from participants and visitors to assist in developing the full programme. The course was held at the BT Technical College, in Staffordshire, and at Bailbrook College, Bath. One week was held at the École Nationale Supérieure de Télécommunications de Bretagne at Rennes, Brittany, France, where the delegates studied European telecommunications, the impact of the Community and 1992.

CONCLUSION

BT has developed a unique and exciting concept for the education of its senior engineering managers. It recognises the major role of engineers in a world-class Telco and the crucial impact of their decisions on the business. It meets the need for senior engineers to have a comprehensive knowledge of telecommunications engineering with emphasis on the business and market dimensions.

The programme is based on an innovative formula for a collective community of learning experience that will enrich the individual. It will breed an *esprit de corps* that will create the top-level cadre of senior engineers that will exert a positive influence to enable the business to meet its future aspirations. The college mission is based on excellence in the visiting faculty, delivery of material, structure of the programme and the logistics of running the programme.

Biography

Keith Ward joined the GPO in 1948 as a Youth-in-Training and his early years, interrupted by service in the Royal Air Force on radar, were concerned with telephone exchange and transmission maintenance and construction duties in the Canterbury Area and Long Distance Area of London. Most of his career has been concerned with network aspects in the London Telecommunications Region and Headquarters. More recently, he led the team that introduced System Y into the network, after which he became Chief Engineer responsible for Planning and Works in National Networks and then BTUK. Currently, as Chief Network Engineer, his prime task has been to establish and run the Telecommunications Engineering Staff College. He is a Fellow of the IEE, has carried out a number of overseas consultancies and ITU missions, and participated in European research projects on network planning.

Future Directions in Long-Haul Optical-Fibre Systems

P. COCHRANE, and D. J. T. HEATLEY†

The last decade has witnessed the progressive replacement and capacity upgrade of copper cable point-to-point links by optical-fibre systems. Repeater spacings have increased more than ten-fold; traffic demand has increased to absorb the available capacity; transmission costs have fallen and very significant savings have been achieved. Optical technology is now dominant in long-haul networks and globally transports over 50% of all traffic. The new optical devices, systems transmission techniques and revolutionary network options emerging from research laboratories look set to eclipse all previous gains. Specifically, coherent optics will allow very high traffic densities per fibre and optical amplifiers offer the possibility of full network transparency. It can therefore be postulated that future long-haul networks will require far less hardware and control, but will offer a much greater utility and reliability.

This article is an updated version of an article that appeared earlier in British Telecom Technology Journal.*

INTRODUCTION

In less than 15 years, fibre optics has emerged from the engineering feasibility study and field trial phase to become the dominant global bit-transport mechanism. For example, the UK currently has 70% of all its long-haul traffic conveyed by fibre systems, while internationally (Figure 1) the total now exceeds 50%. The prime movers for such a rapid exploitation of this (still) emergent technology were both economic and technologically based. On the economic side, fibre systems are inherently low cost owing to their small material demands compared with copper cables. They require dramatically fewer repeaters, power feed equipments, surface stations, duct space and maintenance than the coaxial and twisted-pair systems they replaced. From a technology standpoint, fibre systems also became viable at a time when copper cables were naturally approaching exhaustion. In the UK, for example, coaxial cable repeater spacings had fallen to 2 km for 140 Mbit/s operation by the late-1970s and the future migration to 565 Mbit/s would have required buried repeaters at 1 km intervals. The ultimate capacity of these coaxial cables had, at that time, been established to be less than 1·2 Gbit/s for any wide-scale exploitation[1]. Coupled with the fact that the earthenware duct network was also becoming full of copper, BT faced some very real limits to growth. Interestingly, it is the duct network (and the associated civil engineering) that represents the largest network investment in this respect and its continued exploitation by fibre remains an essential objective.

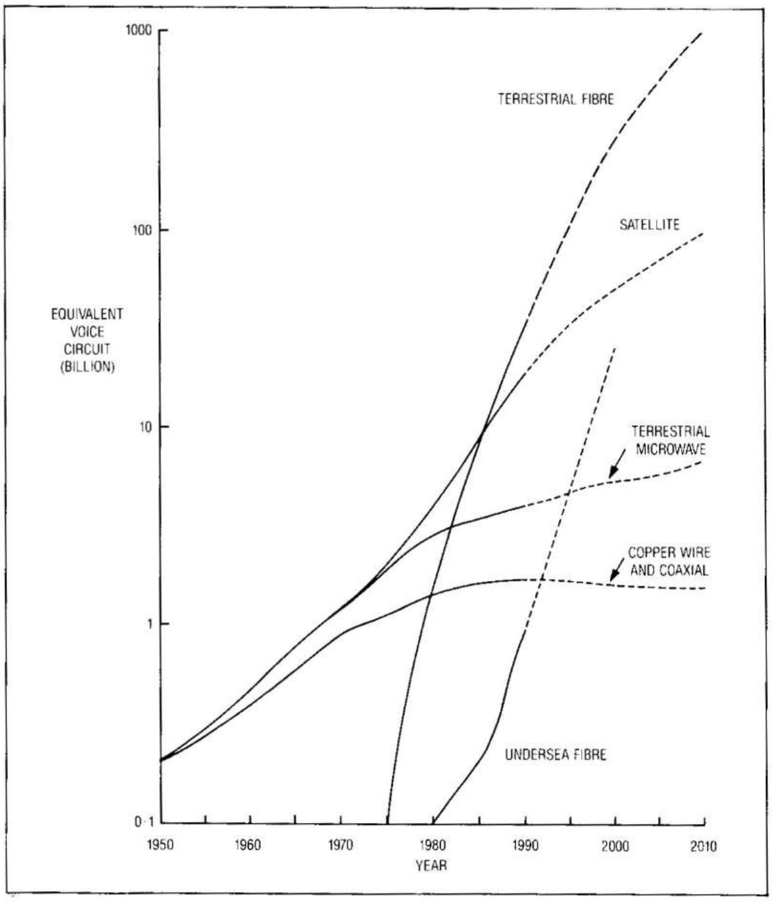


Figure 1
Global transmission capacity

Apart from its very small physical size, optical fibre has two key attributes that make it very nearly the ideal transmission medium—very low loss (less than 0·4 dB/km) and an almost infinite bandwidth (around 50 000 GHz). Exploiting these three elements to supersede directly the established copper cable network of point-to-point links has realised dramatic operational cost savings well beyond the initial investment for the new plant (Figure 2). It is therefore opportune to contemplate what future gains may be realised with the advent of more economic time-division multi-

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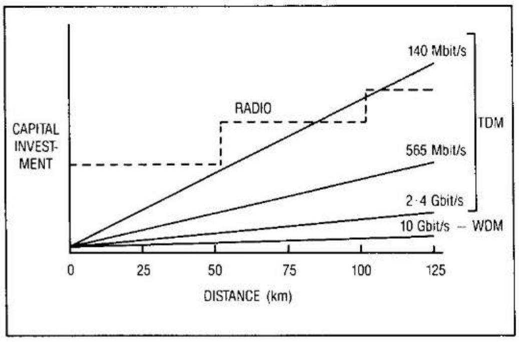
† British Telecom Research and Technology

* COCHRANE, P. Future directions in long haul fibre optic systems. *Br. Telecom Technol. J.*, Apr. 1990, **8**(2), p. 5.

Figure 2
Relative UK transmission costs



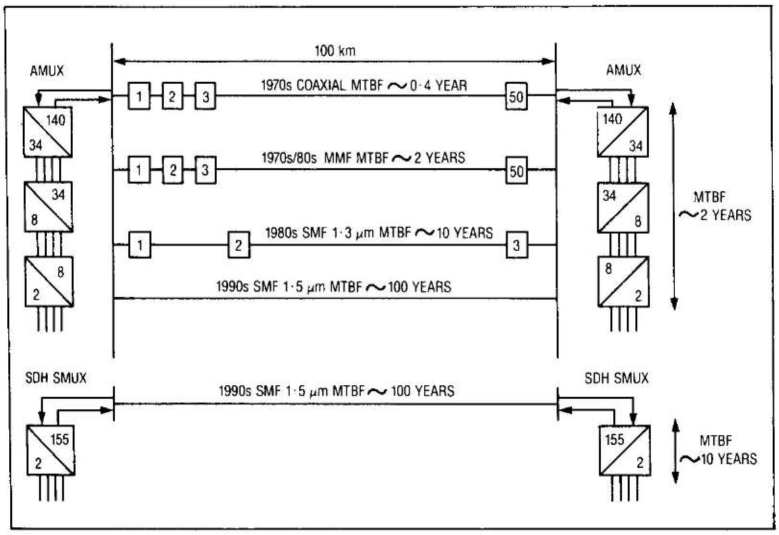
plex (TDM) and wavelength-division multiplex (WDM) options, plus photonic amplifiers, coherent optics and the new network opportunities they offer. This then is the key theme and objective of the remainder of this article.

MIGRATION FROM ELECTRONICS TO OPTICS

The logical migration of long-haul transmission technology is perhaps best illustrated pictorially in terms of the quantity of hardware and resulting impact on link reliability. Figure 3 gives a representative comparison normalised to typical 1970s' reliability figures for the terminal and repeater elements[2]. In practice, the gains achieved have been far greater with the refinement of each technology from 850 nm multimode through 1300 nm and 1500 nm single-mode. At the start of the 1990s, it is clear that the terminal asynchronous multiplex (AMUX) elements are the key impediment to further progress with no 3R (reshape, regenerate and retime) repeaters necessary for 100 km+ span links. Moving to the synchronous digital hierarchy (SDH) or synchronous optical network (SONET) signal format[3] will remedy this to a great extent by reducing the necessary MUX electronics by a further factor of about five. It also offers the option for the switching and add-drop of circuits at the $N \times 2$ Mbit/s or $N \times 1\cdot544$ Mbit/s (T1) rates. The hierarchical standards for this scheme have been agreed internationally, systems are currently being developed, networks are being planned, and it is the next logical step. Any future optical technologies are therefore likely to have to interwork with the existing AMUX and future SDH/SONET hierarchies.

The planned time-scales for SDH/SONET roll-out over a broad range of networks and operators are not envisaged to be significant until mid- to late-1993. Within this time frame, it is also likely that optical WDM technology will become a viable option offering further network options and opportunities[4].

Figure 3
Migration towards synchronous repeaterless working


100 km
AMUX
AMUX
1970s COAXIAL MTBF ~0·4 YEAR
1
2
3
50
140
34
34
8
8
2
1970s/80s MMF MTBF ~2 YEARS
1980s SMF 1·3 µm MTBF ~10 YEARS
1990s SMF 1·5 µm MTBF ~100 YEARS
MTBF ~2 YEARS
SDH SMUX
SDH SMUX
1990s SMF 1·5 µm MTBF ~100 YEARS
155
2
MTBF ~10 YEARS

SMF: Single-mode fibre MMF: Multi-mode fibre
MTBF: Mean time between failures 1·3 µm, 1·5 µm: optical wavelength on fibre

Turning again to Figure 3 and asking the question, what is the next step we could add to the 'wish list'?, it might be supposed that removing the electronic blockage presented by the MUX elements and realising the full bandwidth potential of the fibre throughout a network would be a reasonable objective. This would be a step towards the transmission engineer's dream: a totally transparent network of infinite bandwidth with minimal hardware (and software) of very high reliability. The question is, can it be done, and, if so, when and what will be the technology used and the operational cost advantage?

OPTICAL AMPLIFIER

Over the past five years, optical amplifiers have emerged as promising network elements for the future to the point where they are now becoming commercially available for research and trial applications. Both linear and non-linear devices based on semiconductor and fibre elements have been demonstrated to have useful and controllable characteristics in laboratory and network trials. It is therefore useful at this point to review their operational characteristics, relative state of development and likely future applications.

Semiconductor Amplifiers

The basic travelling wave semiconductor laser amplifier (TWSLA) consists of a Fabry-Perot laser structure with facet reflectivities of less than 10^{-3} to ensure optimal gain, bandwidth, insensitivity to variations in bias current and input polarisation[5]. The fibre-to-fibre gain characteristics of a typical TWSLA are shown in Figures 4 and 5. The TE and TM components refer to the output powers in the transverse electric and magnetic modes of the semiconductor waveguide. These devices inherently possess a degree of sensitivity to input polarisation and for the device shown this accounts for some 3 dB variation of the mean gain. However, careful device design or the use of an automatic gain control system can reduce this effect to be negligible in a systems context.

In common with all optical amplifiers, the TWSLA generates a relatively large quantity of spontaneous emission and this results in a standing optical output in the absence of an input

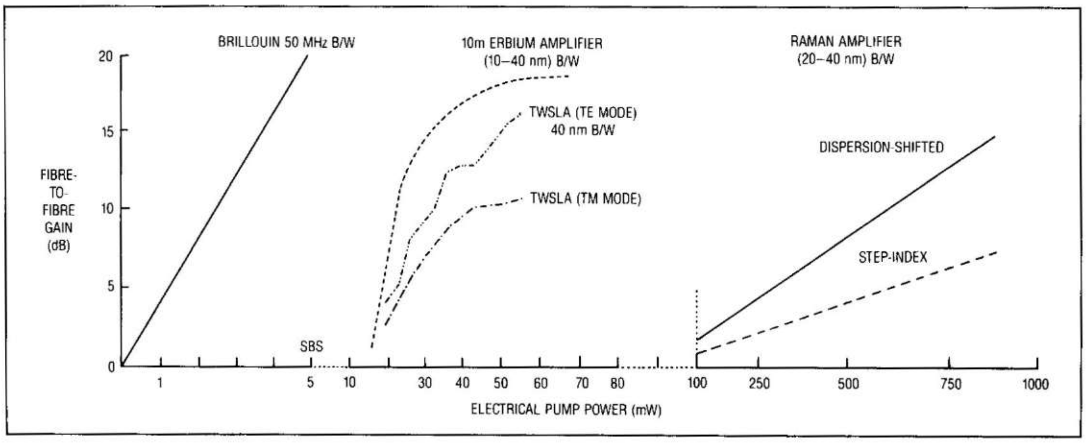


Figure 4
Optical amplifier gain characteristics

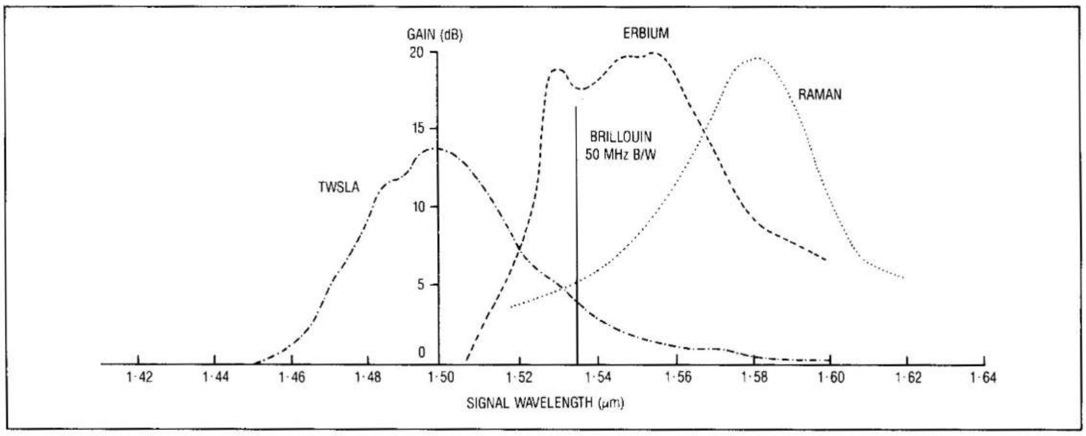


Figure 5
Optical amplifer gain profiles

signal. It also introduces additional noise terms due to 'signal-spontaneous beat noise' and 'spontaneous-spontaneous beat noise'. For a system with N cascaded TWSLAs, these noise terms have been shown to accumulate as N and N^2 respectively[5]. Fortunately, the spontaneous emission profile is relatively broadband, typically occupying some 30 nm, so that optical filtering may be employed as a means of reducing saturation effects. Filters with bandwidths of around 5 – 10 nm may therefore be required for systems spanning more than 500 km. In addition, the small but non-zero facet reflectivity of practical TWSLAs can lead to instabilities in systems owing to the presence of backward travelling waves creating a laser action, and inter-amplifier isolators may be necessary to ensure long-term stability. However, these problems are not thought to be insurmountable as laboratory systems experiments of around 500 km have been reported[6].

In any practical system, the gain of a TWSLA will vary (about ±2 dB) with changes in temperature, device and component ageing, source wavelength and input polarisation. A system is therefore required to control the device fibre-to-fibre gain. One technique that has been developed for a wide range of systems can be implemented using low-speed electronics and no additional optical components[7]. This employs a low-frequency control signal (about 10 kHz) superimposed on the input data sequence to cause a variation in the junction potential which can be detected on the input current. After processing, this signal is used in a feedback control loop to adjust the amplifier bias current.

Apart from the inherent simplicity and low component count, a key feature of the TWSLA is its ability to provide link transparency. Bandwidths of 20 – 50 nm are routinely achievable, whilst experimental multi-quantum-well devices have returned 220 nm; that is, simultaneous photonic amplification over much of the 1300 nm and 1500 nm windows. Exploiting this bandwidth using TDM does not appear to be a significant problem as transform limited pulses of 1·5 ps have been transmitted through a 40 nm bandwidth device without any detectable degradation in pulse shape[8].

Saturation-induced crosstalk poses a significant limitation with today's TWSLA devices, especially with intensity-modulated signals. Coherent optical transmission with constant amplitude FSK or PSK does, however, reduce the problem significantly, and this aspect is still the subject of extensive study.

Numerous long-haul experiments and trials with semiconductor amplifiers have been reported to date with bit rates from 140 Mbit/s to 4 Gbit/s with up to 10 cascaded amplifiers spanning approximately 500 km[6]. A typical configuration and bit-error rate (BER) curve are shown in Figures 6 and 7 respectively for a 500 km five-amplifier system operating at 565 Mbit/s.

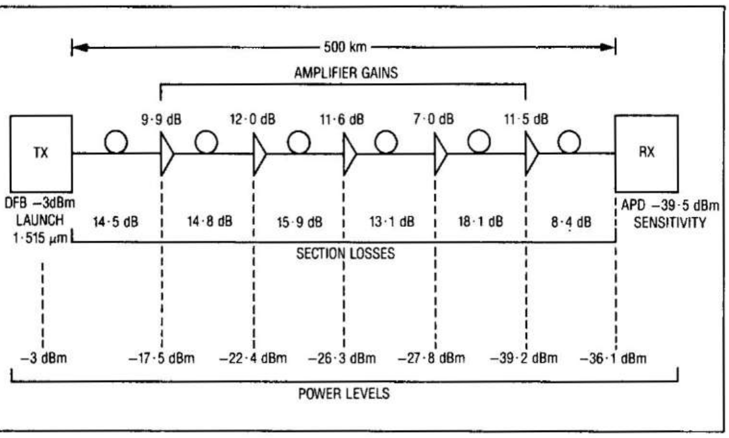


Figure 6—A 565 Mbit/s 500 km TWSLA system experiment

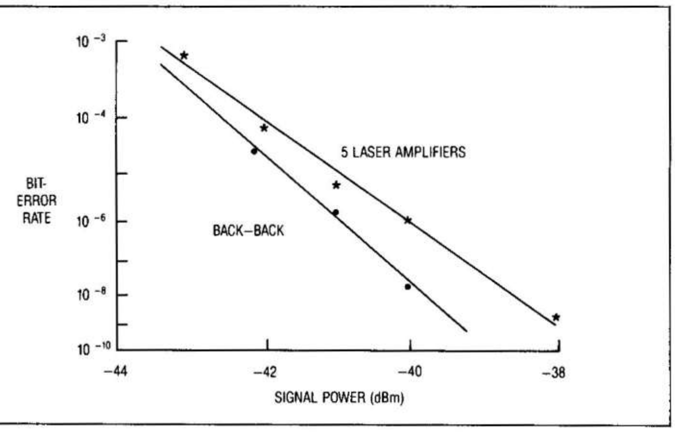


Figure 7—Bit-error rate characteristic for five amplifier system

The Fibre Amplifier

Recent demonstrations have indicated that fibre amplifiers offer significant potential. There are many possible options spanning relatively long lengths (about 10 km) of undoped fibre to short lengths (about 10 m) of doped fibre, and employing the non-linear Raman and (the more limited) Brillouin mechanisms or linear (rare earth–erbium doped) fibre laser amplifiers.

Rare Earth–Erbium Amplifiers

This amplifier depends on material gain defined by the erbium doping of a relatively short section (1–100 m) of silica fibre pumped with optical rather than an electrical energy. Alumina doping can be used to broaden the bandwidth and about 40 nm can be achieved (Figure 5). Because of the efficient coupling of the fibre-to-fibre splices, high gains (approximately 30 dB) are achievable with optical pump powers of around 50–100 mW (Figure 4). At present, solid-state pumps operating in the region of 1480 nm are favoured, mainly because they are available, but higher efficiency of operation (twice the gain figure) can be realised with a pump at 980 nm. These are currently under development and are not yet readily available. Two interesting features of these amplifiers are the precise definition of the operating wavelength via the erbium doping and their relative immunity to signal-dependent effects owing to the long carrier recovery time. They can therefore be engineered to maintain wide bandwidths when cascaded, and operate equally well with OOK, FSK and PSK signals. Crosstalk and intermodulation are not as significant a limitation as that experienced with TWSLAs which have short carrier recovery times[9].

Raman Fibre Amplifiers

Injecting a high-power laser beam into an undoped (or doped) optical fibre creates a Raman scattering spectrum that extends to longer wavelengths than the pump. In standard single-mode optical fibres, there are relatively low concentrations of germania in the core and this results in the peak Raman gain being achieved with a wavelength difference between the pump and signal of about 100 nm in the 1500 nm window[10]. Introducing a lower-intensity signal-bearing beam into the same fibre with the pump energy results in its amplification by an energy transfer owing to the non-linear scattering process induced by molecular vibrations in the glass structure. Relatively high gains (approximately 15 dB per watt of pump power) coupled with wide bandwidths (approximately 50 nm) can be achieved (Figures 4 and 5).

It is presently difficult to create a laser action within a Raman amplifier as it requires very high energy concentrations, and the device is therefore considered to be inherently stable. In common with the previously described amplifiers, it is also capable of duplex operation, and with a suitable doping of the fibre can offer a 40 nm bandwidth. However, the optical pump power required tends to be high (approximately 200 mW) at a wavelength of about 1470 nm (Figure 4).

Brillouin Fibre Amplifiers

Stimulated Brillouin scattering is a very efficient non-linear amplification mechanism[11] that can realise high gains (Figure 4) with modest optical pump powers (around 1 mW). However, the resulting bandwidth (Figure 5) tends to be very limited (about 50 MHz) in pure silica which makes such devices useful as narrow-band tunable filters in WDM system amplification. This limiting bandwidth, which fundamentally restricts the use of Brillouin amplifiers to relatively low bit rate communication systems, cannot be overcome to any significant degree by doping the core, although it is possible to use germania to create a broadening of the spectrum to 100–200 MHz. The fibre may be pumped with a CW laser at a power of between about 5 and 10 mW to realise gains in excess of 15 dB, but a very precise frequency difference (about 11 GHz) has to be maintained between the pump and signal to ensure the Brillouin phenomenon is maintained. This type of amplifier is thus thought to have a very restricted range of application.

A Comparative Summary of Key Features

An exhaustive comparison of the features of optical amplifiers is not yet possible as many of the fundamental aspects are still being investigated. For example, the present understanding of the basic noise accumulation mechanisms for cascaded amplifiers, non-linear distortion, the ultimate transmission length limitations for linear and digital operation are still questionable. However, what is clear from published results is that systems of about 2000 km in length (see Figure 11 later) are feasible today with suitably engineered components. In this context, it is possible to draw the following comparisons:

(*a*) TWSLA and erbium amplifiers require similar pump power (electrical) whereas Raman is substantially higher.

(*b*) TWSLAs realise less fibre-to-fibre gain owing to the inherent fibre coupling losses and are polarisation sensitive.

(*c*) The very wide bandwidth of TWSLA, and some erbium-doped fibre amplifiers promotes a rapid build-up of spontaneous emission noise leading to early gain saturation which may necessitate the use of optical filters on very long systems.

(*d*) Poor splice and facet reflectivities can drive TWSLA and erbium amplifiers into a laser condition and careful control is necessary to maintain system stability.

(*e*) Erbium amplifiers appear to have the lowest noise and crosstalk performance of all the amplifier types reported.

(*f*) The need for high-power optical pumps currently renders fibre amplifiers inherently less reliable than the TWSLA. However, the use of multi-laser pump circuits may overcome this limitation.

(*g*) The end-to-end bandwidth of a cascade of TWSLA amplifiers is dictated by the careful control of chip characteristics which defines the precise pass-band and centre wavelength of each amplifier. Temperature, ageing and bias (pump) current can significantly influence these parameters.

(*h*) For fibre amplifiers, the bandwidth and centre wavelength are mainly defined by the atomic structure and not the mechanical geometry. Variations due to temperature, ageing and pump power are therefore less significant.

With the exception of the Brillouin, the amplifiers considered can be expected to be used across a broad front of system applications including, transmitter power amplifiers (Raman), receiver pre-amplifiers (erbium and TWSLA), in-line repeater amplifiers (Raman, erbium and TWSLA) and switches. These categories are identified in Table 1. Figures 8 and 9 show examples of packaged submarine and terrestrial repeaters which incorporate TWSLA and erbium amplifiers respectively. Figure 10

TABLE 1
Optical Amplifier Applications

Application	TWSLA	Erbium	Raman	Brillouin
Power amplifier	√	√	√	X
Repeater	√	√	√	X
Receiver preamplifier	√	√	X	narrowband only
Selective filter	X	X	X	√
	bidirectional			unidirectional

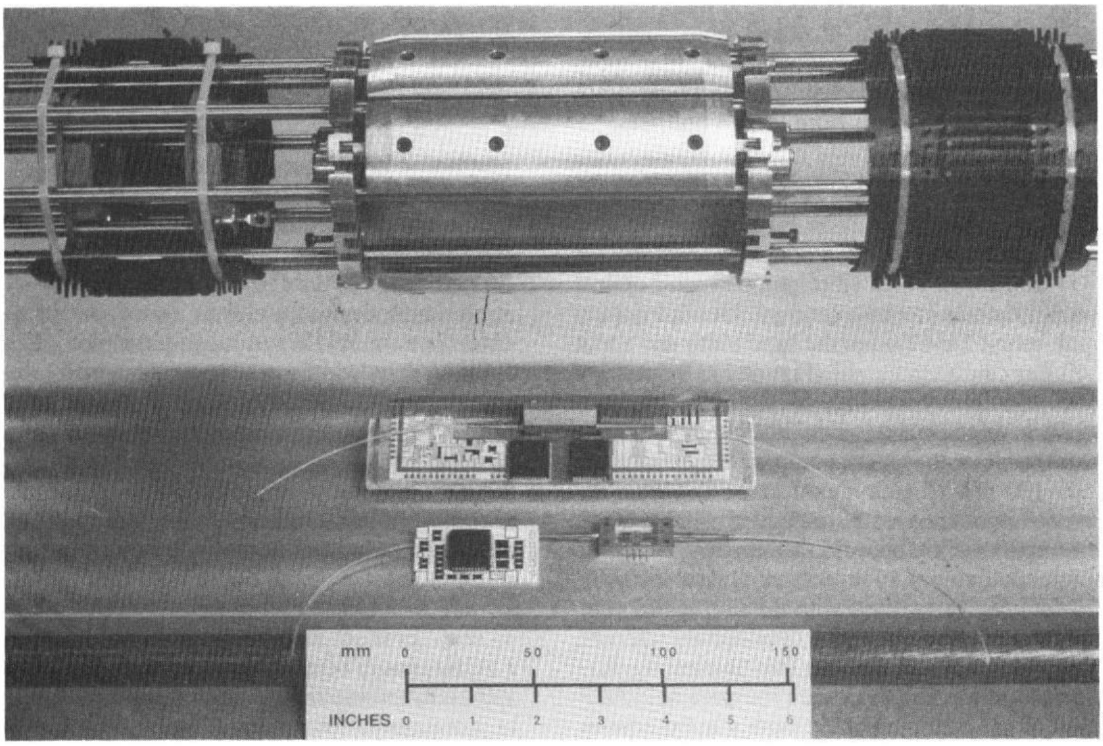


Figure 8
Future undersea repeater assembly and optical amplifier

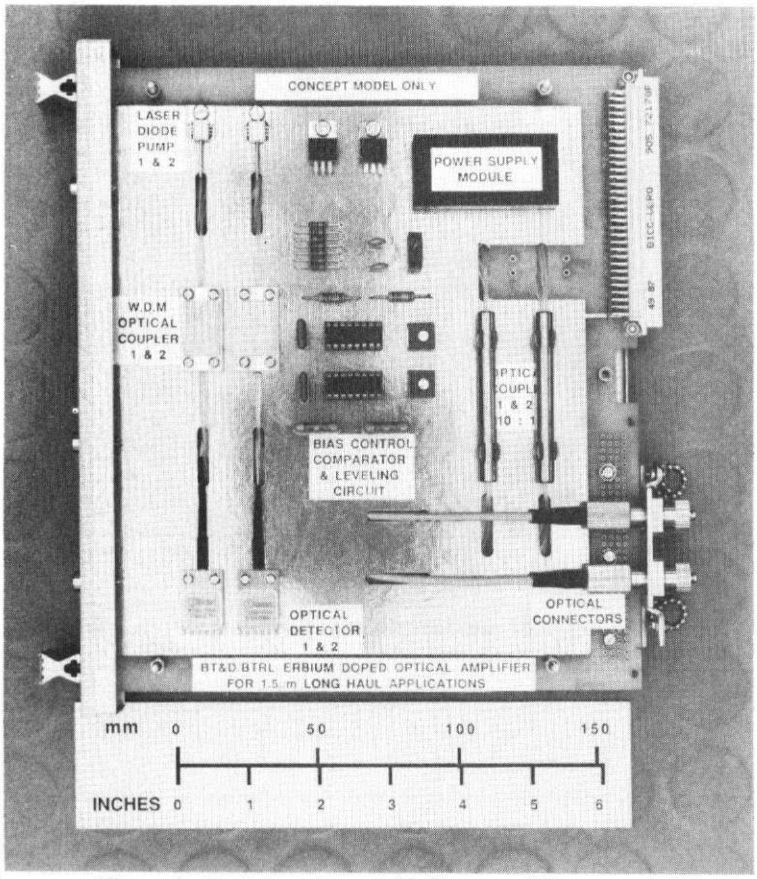


Figure 9—Prototype terrestrial fibre amplifier repeater

Figure 10—Commercial erbium fibre amplifier for laboratory use

shows a commercial erbium amplifier developed for laboratory use.

OPTICAL AMPLIFIERS—SYSTEM POTENTIAL

From an operational standpoint, the optical amplifier offers unparalleled flexibility and utility. It has a demonstrated ability to convey conventional analogue and digital signals, in AM, FM and OOK, FSK, PSK formats respectively, over considerable distances (Figure 11). In principle, the mix of signal types and format is unimportant—all could coexist in the same fibre and amplifiers—at multi-Gbit/s information rates. Moreover, and in this case uniquely, optical amplifiers can also sustain soliton (perfect wave) propagation[12].

In broad terms, the limiting signal-to-noise (S/N) ratio of an amplified system may be approximated by:

$$\mathrm{S/N} = \frac{4P_o}{NG\eta B} \qquad \ldots(1)$$

where P_o = amplifier output power,
N = number of amplifiers,
G = amplifier optical gain,
B = bit rate, and
η = spontaneous contribution factor.

For a BER of 10^{-9}, equation (1) predicts that N is greater than 300 and spans approaching 50 000 km could be realised. However, when fibre dispersion, laser chirp, linewidth, modulation rate and format are taken into account, this optimistic estimate rapidly becomes more modest[13] as indicated in Figure 12.

For intensity-modulated systems, laser chirp and fibre material dispersion broaden the optical pulse and severely limit both the speed and distance of transmission. Even with coherent optical transmission, which removes laser chirp-related dispersion, the finite linewidth and spectral spreading due to the modulation poses a significant transmission distance limitation. Taking, for example, a dispersion-shifted fibre at 2·5 ps/nm km, the bit rate $\sqrt{L}$ product for a 3 dB dispersion penalty is approximately 200 Gbit/s $\sqrt{\mathrm{km}}$. This limit is also given in Figure 12 for the coherent PSK, dispersion shifted and standard fibre cases. All other unknown phenomenon withstanding, transoceanic and transcontinental systems look feasible!

There now remains one significant worry—the impact of low level non-linearities on very long amplified systems operating in a linear mode. Theoretically, the limit to linear operation appears to be 1000 km. Practical evidence denies this with recent linear transmission at 10 times the theoretical. However, if the build up of non-linear effects actually manifests itself as a fundamental limit to transmission distance, there is one possible contender to sidestep the problem—the soliton. This type of wave is 'perfect' and can be sustained only by a non-linear medium for any appreciable distance. Recent results have shown the practical generation and transmission of soliton pulses over 100 km with a mid-span erbium-doped fibre amplifier. Pulses of 8 ps duration were launched at a power level of 20 mW and bit rate of 20 Gbit/s and emerged with an unchanged width of 8 ps (Reference 12).

OPTICAL PIPES AND FAULT LOCATION

Because the semiconductor, erbium-doped, TWSLA and Raman amplifiers are capable of simultaneously amplifying photons in both directions, it is possible to use optical time domain reflectometry techniques for fault location[14]. Figure 13 shows a system of three amplifiers being probed by an optical time domain reflectometer (OTDR) with the associated backscatter traces from each fibre section accompanied with a gain step for each amplifier. The front-to-back facet gain is visible in the form of a large spike above the main step in the backscatter response. It is thus possible to identify remotely faults due to fibre and amplifier related problems. It has been estimated that this technique would remain effective in a practical arrangement for system lengths up to 1000 km. Beyond this, the detection process is defeated by the build-up of noise. However, if the individual section gains and fibre losses were precisely controlled and matched, then a system length OTDR range could be realised.

Beyond the OTDR technique, which is almost ideal in its simplicity, other solutions have been developed for the detection and location of faults through the correlation of bit errors[15]. For duplex operation, this technique is currently the most accurate location method, while for simplex, it relies upon very high bit rates for good resolution.

It is also possible to fall back on the old analogue supervisory techniques which were largely based upon supervisory tones, that is, a discrete signal injected at each amplifier in a band unused for information transmission—a very simple and proven system that can relay information on amplifier gain, pump power and other 'DC' performance metrics.

SIGNAL FORMAT

Optical-fibre systems are currently dominated by very simple intensity-modulated systems with no inherent signal selection at the receiver. Lasers are merely 'turned on and off' by current pulses and the photons detected directly by APD or PIN diodes. The sudden change in carrier density that results in a laser induces broad wavelength shifts in the emitted light and they are thus bit-pattern dependent and 'chirp' at different rates and points in a bit sequence. For example, a DFB laser with a 50 MHz linewidth at 1535 nm operating at 2·4 Gbit/s can typically broaden to 60 GHz due to chirping. In turn, this results in pulse dispersion with the energy displaced from the zero dispersion wavelength. This is a key limiting mechanism to long-distance transmission and might typically preclude the span length to 60 km with 2·5 ps/nm km fibre. An obvious solution to this problem is the use of a constant-amplitude FSK format with the laser drive current modulated by a small current deviation to minimise the effect of chirping. This then allows the system to operate over 1000 km or more.

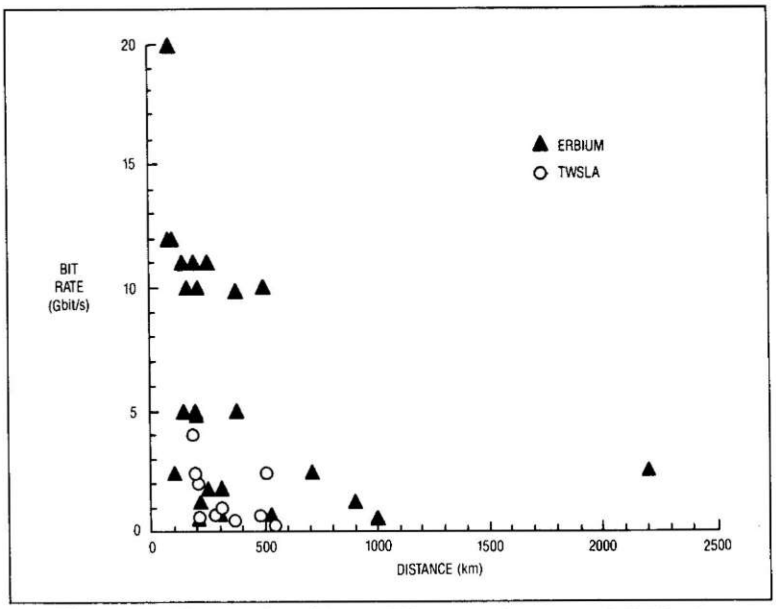


Figure 11—Reported multi-amplifier experiments and field trials

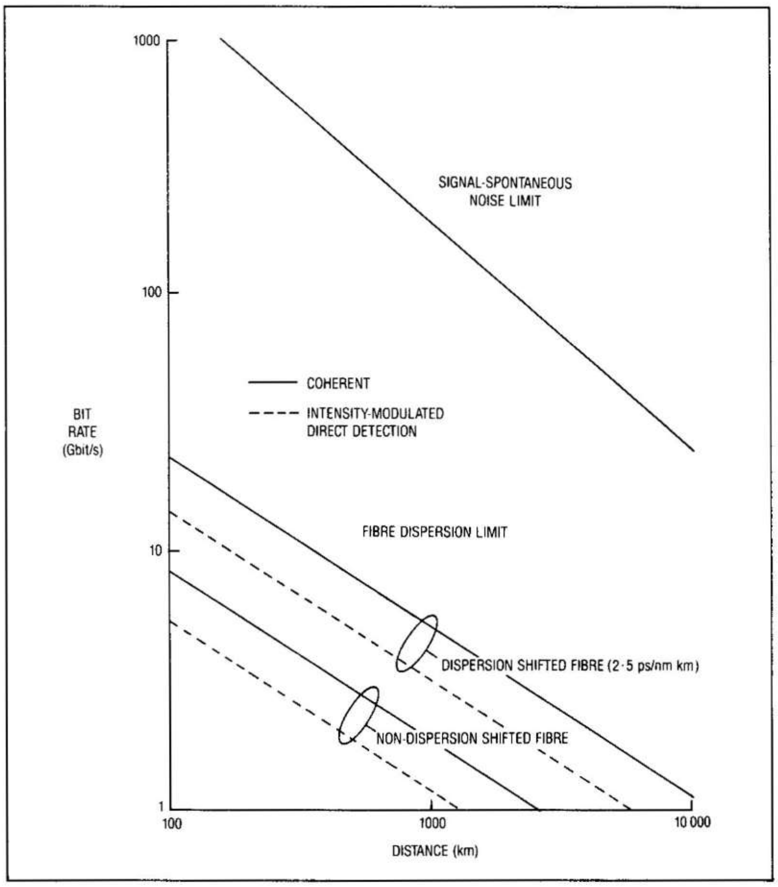


Figure 12—Bit rate versus distance limitations for a 1500 nm system with 20 dB gain amplifiers (output power = 0 dBm; BER = 10^{-10})

A further solution requires an external modulator and optical isolator to allow the laser to operate in an unmodulated CW mode. This produces a better result, but at the expense of launch power due to the optical loss of the modulator and, usually necessary, isolator. An optical amplifier can be used here to recover the power lost.

More recently, the need to transport signals at very high bit rates has led to the development of WDM and sub-carrier modulation (SCM) schemes, which closely resemble their analogue

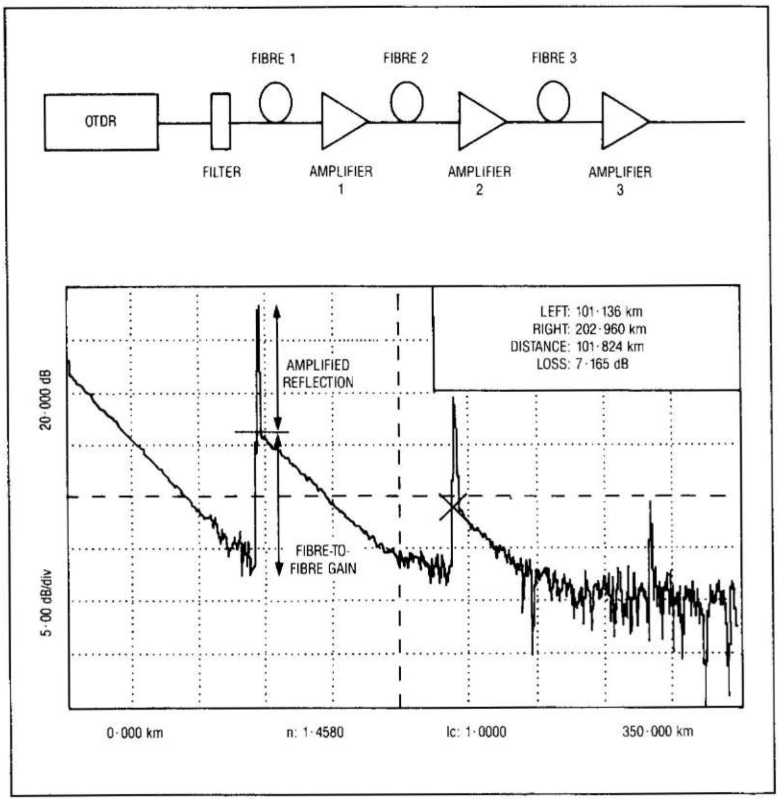


Figure 13 OTDR response from a TWSLA system

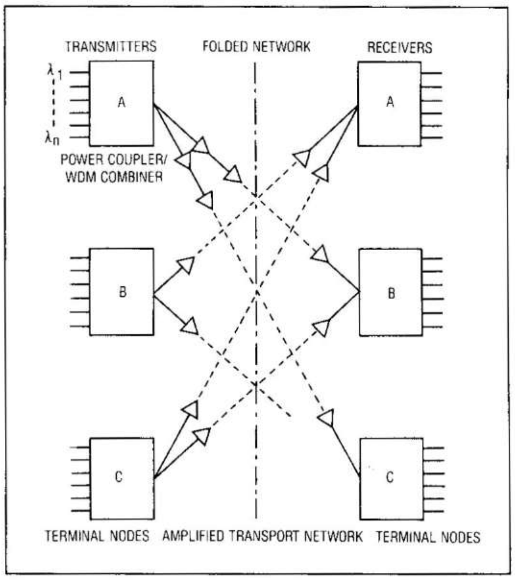


Figure 14—A fully interconnected optical ether

FDM predecessors[16]. Assembling such signal 'stacks' is relatively straightforward, but their successful amplitude-modulated transmission is subject to a high degree of transmission path linearity. The fact that the majority of the past device development effort has been concentrated on digital applications does not help as linearity has not been of any significant concern. However, the use of analogue FM modulation of the optical source generally overcomes this problem[17], and signals in this format have been transmitted over 1000 km with 10 or more optical amplifiers in cascade at capacities of 16 Gbit/s or more.

FUTURE NETWORKS

So far, optical-fibre networks have merely provided a direct replacement of their copper predecessors on a point-to-point basis. The next step will be the exploitation of the inherent capacity of fibre, which is approximately 50 000 GHz per individual fibre. Passive optical network research for future local line applications is already well advanced, and the notion of wavelength routing/switching established[2,16]. The emergence of the optical amplifier now offers the promise of similar technological advantages in long-haul networks. Pictorially, a future long-lines network might be envisaged as shown in Figure 14. Here each node is fully interconnected through the transparent couplers and optical amplifiers to form a universal 'ether'. Network operation might resemble the presently established satellite and radio networks: select a station through wavelength, time-slot and/or code. The operational options are vast but could easily embrace the past, present and future signal formats and signalling protocols.

The topology of ether networks can take the form of stars, trees, and rings. All of these options can be optimised for reliability, survivability[18] and utility; by and large, it is not dictated by the technology, and its operation is therefore insensitive to the final choice. Realising the full ether potential, however, does necessitate the tight packing of information onto the individual fibres, otherwise fibre-intensive solutions result with many overlays of the basic network.

To date, demonstration networks have been confined to the laboratory, but some very impressive results have been reported. For example, a total of seven nodes at 52 km spacing has been fully interconnected with 150 GHz of bandwidth simultaneously available between any two nodes in the network[19]. The addition of optical amplifiers and coherent optics would enhance this capability further.

COHERENT OPTICS

The development of coherent systems is often referred to as being as significant as the move from 'spark transmitters' to 'oscillators and heterodyne systems' in radio terms. Present optical systems (spark transmitters and direct detection) access less than 0·005% of the available fibre bandwidth. In contrast, coherent systems offer the potential to access more than 5%. This fact alone has emerged as probably the key advantage that coherent optics has to offer in the wide-scale application to future networks[20].

The optical sources required generally have linewidths of less than 20 MHz for FSK modulation and less than 1 MHz for PSK. The broadening of this linewidth when externally modulated is only of the order of the bandwidth of the signal. It is therefore possible to span

200–300 km at 565 Mbit/s, for example, without any intermediate repeaters and to pack WDM channels close to the stabilising limit of the carrier sources.

A wide range of coherent systems has been investigated that share a common set of characteristics[21]. Firstly, coherent receivers are inherently selective through the heterodyne process, which affords a far higher detection sensitivity (typically more than 10 dB) than direct detection. Secondly, systems are sensitive to polarisation in that the state of polarisation of the local laser (local oscillator in radio terminology) has to be aligned with that of the received light. The only exception to this case is when polarisation-maintaining fibre and/or polarisation-diversity receivers are used. Thirdly, coherent signals can be packed very tightly into the available signal space, with about 10 GHz demonstrated in field trials. This compares with about 1 nm (about 150 GHz) with conventional systems, which therefore require 10–100 times the signal space of coherent systems (and more than 1000 times when source chirping is included in the comparison). For the very longest amplified systems, which have a narrow bandwidth and linearity constraints, then constant amplitude coherent systems offer a distinct advantage.

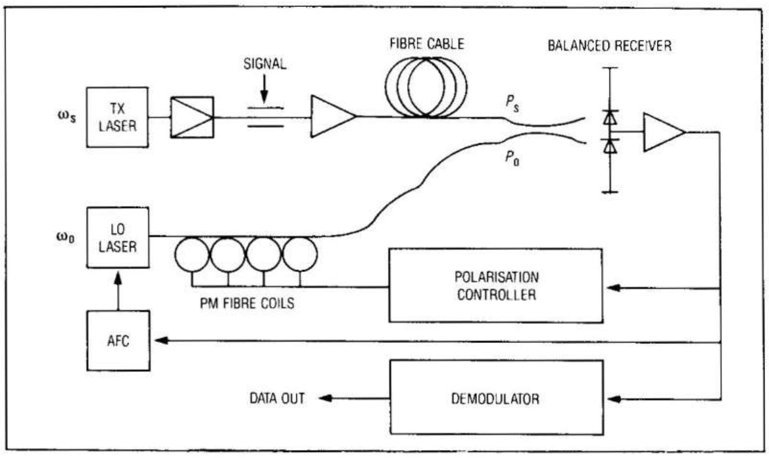
The essential elements of a coherent system are shown in Figure 15 with the polarisation-matched signal and local oscillator giving the following power at the input to the IF filter:

$$P_I = P_S + P_O + \underbrace{2\sqrt{(P_S P_O)}\cos(\omega_S - \omega_O)t}_{\text{intermediate frequency term}} \quad \ldots (2)$$

Increasing the local oscillator power P_O allows the receiver sensitivity to approach the quantum noise limited value. In practice, however, device and circuit limitations such as coupling losses, quantum efficiencies, mixer performance and filter realisation dictate that there are always a few decibels (about 2–5) of additional penalty. Indeed, there is some debate about the precise limits, in photons/bit, to detection sensitivity in this arena! What has been demonstrated, however, is that there is a significant advantage available (greater than 10 dB) in some application areas[22].

Coherent Sources

A standard Fabry-Perot (FP) cavity laser is generally multi-moded with a linewidth of about 100 MHz and a total energy spectrum spread of about 10 GHz in an unmodulated state. The direct application of bias current modulation can result in a spread of about 1000 GHz. Clearly, this device is unsuitable for coherent applications. The addition of a selective element (filter) internal or external to the FP cavity allows a single mode of oscillation to be selected/forced. This is the fundamental basis of all the currently available semiconductor sources suitable for coherent systems.



AFC: Automatic frequency control

Figure 15
Elements of a coherent trasmission system

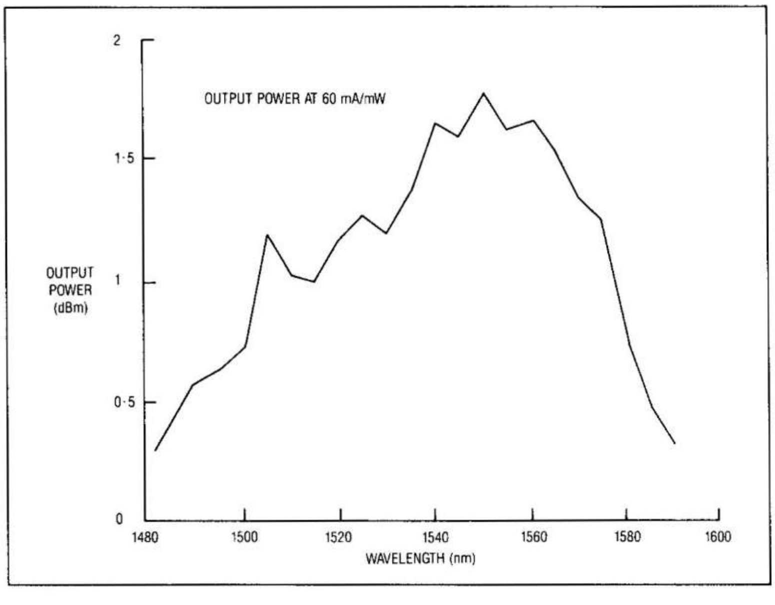
Three types of laser sources have proved particularly successful in laboratory and field trials. There are the distributed feedback (DFB), distributed-Bragg reflector (DBR) and long external cavity (LEC) lasers. The DFB (which is commercially available) and DBR (which is a research device) lasers have integral (on chip) resonator structures that select an individual mode and give linewidths of about 1–100 MHz. This tends to restrict their use to FSK, and PSK at very high bit rates. In contrast, the LEC laser (which is commercially available) offers linewidths of less than 100 kHz making it applicable to PSK and DPSK systems[23].

From a networking standpoint, it is desirable to be able to tune continuously a coherent source across a wide range of wavelengths, while maintaining all the single-mode properties. This is currently proving difficult, but significant progress has been made toward this goal as indicated in Figure 16.

Wavelength Control

On a point-to-point basis, tightly-packed WDM requires only the differential spacing of the channels to be maintained. This can be achieved

Figure 16
LEC laser output power with electromechanical tuning



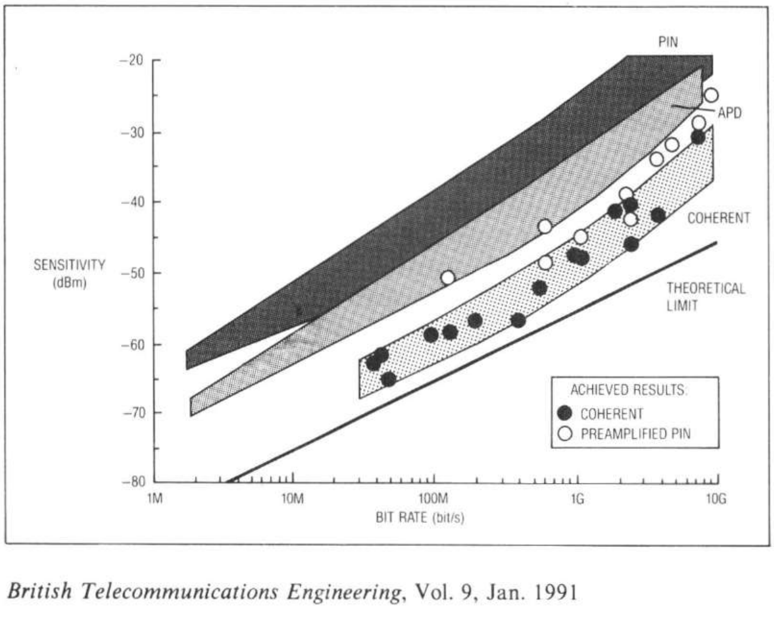
by 'beating' adjacent carriers to produce a difference signal at microwave frequencies, and thereby facilitate the accurate control of laser sources via an electronic feedback loop. In a network context, this problem may be escalated to require absolute wavelength determination and control. An alternative would be to let one node act as the 'master source' with all other slave nodes 'riding' its free running reference signal. As networks become large and the prospect for failure increases, which in turn dictates complex control 'handover' protocols, especially between operating companies and countries, for example, wavelength references become essential. In short, optical frequency synthesisers are required with an atomically-defined reference[21]. At present, the helium-neon gas laser offers the simplest reference source. This can be modulated by a microwave source to produce a 'comb' of reference signals spanning 100 GHz or more. It can also be used to mode lock one or more lasers to generate a comb over a substantial proportion of the 1300 nm and 1500 nm windows.

This is an important area that will require substantially more investment than hitherto in order to realise the full potential of future transparent optical networks.

Polarisation

The single-mode fibre presently installed in networks supports the transmission of two orthogonally polarised modes that are generated by the physical state of the cable/fibre. Disturbances arising from temperature changes, stress relief, maintenance action and severe vibration/movement of cables result in unpredictable changes in the received polarisation state. If uncontrolled, these produce deep 'fades' at the receiver. There are principally four ways to overcome this problem: polarisation maintaining fibre; polarisation control; polarisation scrambling; and diversity receivers. The first option is of little use as most operators wish to use their installed fibre which is not polarisation maintaining. Polarisation scrambling can result in a significant reduction in link capacity and in certain circumstances can introduce up to a 3 dB sensitivity penalty.

Figure 17
Best reported receiver sensitivities



Given that naturally induced changes in polarisation tend to be slow, a favoured solution is to introduce an automatic control loop in the local oscillator arm (Figure 15). The polarisation control transducers can be electromechanical or electro-optic devices, both of which allow endless tracking of polarisation changes[24]. The electromechanical devices achieve a rotation in the polarisation by distorting the essentially symmetric fibre structures through compressive or stressing forces. Electro-optic devices, such as those fabricated on lithium niobate, utilise waveform rotation under an electrostatic field to provide a more mechanically compact realisation. However, they suffer from a higher material loss, which has to be compensated for by higher levels of local oscillator power.

Receivers

The bandwidth of the signal from a coherent receiver is generally broader (sometimes significantly so) than the bandwidth of the transmitted message. Furthermore, in order for the noise penalty resulting from the optical mixing at the photodetector to be minimised at realisable local oscillator power levels, receiver noise must itself be low. Practical coherent receivers must therefore be both broadband and low noise. Bandwidths of around 10 GHz can now be readily achieved[25] with certain examples exceeding 15 GHz, while noise levels are generally less than 15 $\text{pA}/\sqrt{\text{Hz}}$. This noise level corresponds to a sensitivity penalty of only about 3 dB for a local oscillator power of −3 dBm.

By using two matched photodetectors in a balanced configuration (Figure 15), more efficient use is made of the signal and local oscillator power. In addition, intensity noise arising from the local oscillator is removed at the receiver because it appears in phase at the photodetectors, while the beat signals are in anti-phase. Since the photocurrents through the photodetectors are subtracted, local oscillator intensity noise is cancelled but the beat signals add constructively. The shot noise limit can therefore be more closely approached. This is evident in Figure 17, which charts the best reported sensitivities for coherent systems.

It is clear that coherent systems give an approximately 10−15 dB sensitivity advantage over direct detection systems. However, rapid progress has been made recently in developing direct detection receivers which incorporate optical preamplification to improve overall sensitivity. Early work in this field used semiconductor laser amplifiers[5,26] and substantial sensitivity improvements were reported[27–29], but polarisation dependency gave rise to intermodulation between wavelengths, and coupling losses to and from the laser amplifier were high. More recently, attention has shifted to erbium amplifiers because of their benefits described earlier. Recent experiments in this field[30,31] have produced sensitivities within a few decibels of the best reported coherent sensitivities (Figure 17). This, coupled with the intrinsic simplicity of direct detection systems, would appear to reduce the attraction of coherent systems. On the other hand, the channel selection properties of coherent receivers in terms of channel spacing and tuning range have yet to be rivalled by direct detection technology.

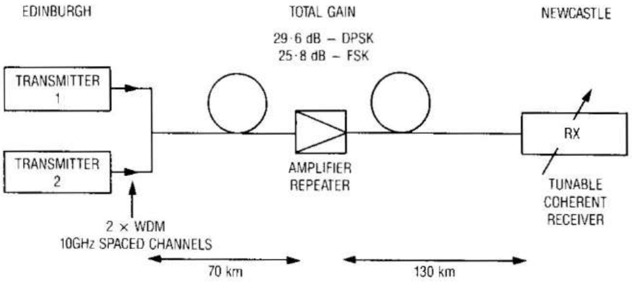
Demonstrators

The vast majority of reported systems have resulted from laboratory configurations at bit rates from 140 Mbit/s to 8 Gbit/s with fibre spans from 90–300 km. So far, there have been very few field trials with equipment that resembles a fully deployable system[21]. In particular, KDD has demonstrated 565 Mbit/s transmission over 90 km of fibre in an undersea cable, while BT has installed several terrestrial trials with 565 Mbit/s over 176 km between Cambridge and Bedford and 2 × WDM (10 GHz spacing) 622 Mbit/s over 200 km between Edinburgh and Newcastle with an intermediate erbium amplifier. In the latter case, both DPSK and FSK modulation schemes were used with LEC and DFB laser sources respectively[32]. The power budget and fibre losses for these trials are given in Figure 18.

BIT RATES

In Europe, Japan and the USA, long lines optical networks have been established operating at 90, 140, 565 and 1700 Mbit/s. The move to 2·4 Gbit/s is imminent and the next major step is likely to be 10 Gbit/s. Optical devices do not pose a fundamental limitation to this progression, but electronics ultimately will. Although 10 Gbit/s looks reasonably certain, moving to higher rates of around 20–40 Gbit/s looks increasingly doubtful. However, optical processing at these rates should, in principle, be reasonably straightforward. So far, true TDM 20 Gbit/s rates have been demonstrated with mode-locked lasers and external modulators, while 30 Gbit/s WDM has also been proved to be feasible.

While the final outcome of the speed race between WDM and TDM may be decided by the supercomputers of tomorrow, it is already evident that there is a reasonable chance of being able to achieve 100 Gbit/s TDM with optical bit-interleaving techniques. It is extremely unlikely that electronics will be able to approach this rate. Furthermore, the passage of such bit streams through optical amplifiers and other components does not pose any foreseeable limitations. Perhaps a more likely arbiter on the final outcome will be the reliability issues concerned with the concentration of information onto single rather than multiple paths.



	FSK Ch. No. 1	 Ch. No. 2	DPSK Ch. No. 1	 Ch. No. 2
Launch power/channel	−1·3 dBm	−2·3 dBm	−5·3 dBm	−8·0 dBm
Route Loss (70 km)	−21·5 dB	−21·5 dB	−21·5 dB	−21·5 dB
Total Repeater Gain	+25·8 dB	+26·8 dB	+29·7 dB	−31·0 dB
Route Loss (130 km)	−43·5 dB	−43·5 dB	−43·5 dB	−43·5 dB
Received Power	−40·5 dB	−40·5 dB	−40·6 dB	−42·0 dB
System Sensitivity	−44·1 dBm	−44·1 dBm	−48·1 dBm	−48·1 dBm
Total Margin	+3·6 dB	+3·6 dB	+7·5 dB	+6·1 dB
Total Budget	+68·6 dB	+68·6 dB	+72·5 dB	+71·1 dB

Figure 18—BT 622 Mbit/s coherent field trial

A QUANTIFICATION OF ADVANTAGES

The advance of optical-fibre technology at the long lines level in networks has already returned significant operational advantages. During the next phase, when the systems technology will migrate to optical networks, the gains will be even greater. Specifically the following broad, but incomplete, quantification gives a measure of what might be expected:

(*a*) Replacing the electronic 3R repeaters with optical amplifiers will give a component count reduction of more than 15:1 leading to significant improvements in link and network reliability.

(*b*) In the BT case, the direct interconnection of major network nodes by the use of coherent optics would eradicate all intermediate repeater sites. It is now possible to fibre directly London–Birmingham, London–Bristol, Birmingham–Manchester, Manchester–Leeds, etc. A resulting building stock reduction of more than 50% might therefore be contemplated.

(*c*) The opportunity for self-induced network faults is jointly reduced by (*a*) and (*b*) at an estimated improvement factor of more than 10:1.

(*d*) The need for network surveillance and management hardware and software is reduced by more than 10:1.

(*e*) Introducing full network transparency and wavelength routing would reduce the number of (true discrete) switches necessary by a factor of more than 5:1.

(*f*) The reuse of existing fibre by dense WDM signal packing would afford substantial investment savings. Existing fibres are capable of supporting traffic levels of more than 1000 times their present traffic levels.

(*g*) Network capacity expansion via any other mechanism is probably unachievable.

In all of this there are some significant conflicts and risks. For example, the 'bits are free' nature of optical networks with their almost infinite bandwidth mitigates against asynchronous transfer mode (ATM) networks with their accent on bandwidth efficiency. Similarly, SDH/SONET 'add-drop' technology may well be eclipsed by simpler WDM options with the passive 'add-drop' feature of transparent networks. The coexistence and commercial timing of these offerings is thus going to take some sensitive management. This is especially so as the rate of optical technology development continues to accelerate.

On the undersea cable side, the 'optical pipe' represents the ultimate system solution[33]. An ability to transmit 565 Mbit/s over 300 km without a repeater satisfies 30–40% of the world market in terms of system numbers. Beyond this, a span of 300–2000 km would satisfy a further 50% or so, and the remainder require lengths up to 6000 km. For those systems (greater than 300 km) requiring repeaters, the optical amplifier offers considerable advantages[34]:

(*a*) A reduction in physical size allows repeater housings to fall to about 0·1 of their present volume.

(*b*) Cable size may also be reduced which leads to better handling and storage properties, plus lower costs.

(*c*) Shipboard handling and laying costs can therefore be reduced.

(*d*) Power feed current may be substantially reduced.

(*e*) Capacity upgrades will only require changes at the terminal equipments; that is, the systems have a degree of future proofing

At present, the conventional 3R repeaters represent about 10% of the total system costs, while the laying operation can account for 40%. It is therefore the fundamental cable design/size/use of materials and laying where future cost savings have to be sought. But these are unlikely to be as significant as those achieved by subsequent capacity upgrades through transparency.

THE FUTURE

This article has concentrated on the developments in silica fibre technology and networks. Beyond the continuous doping of silica to produce distributed amplifiers that provide gain throughout the entire length of a transmission span, which is the ideal for a WDM/analogue based network, there is little scope for fundamental advance due to the Rayleigh scattering limitation. Moving to longer wavelengths with fluoride/halide fibres could, in theory, produce a fundamental reduction in fibre loss by 10–100 times that of silica. This would only reinforce the theme of this article and make even more certain the emergence of transparent (ether) networks. To date, the lowest loss of such fibre stands at 2 dB/km in short lengths with some formidable strength and toxicity problems remaining. But the rate of progress does appear to mirror the previous history of silica. As with many other technologies, silica versus GaAs, for example, the question is, will silica forestall mid-IR fibre development?

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Biographies

Peter Cochrane graduated from Trent Polytechnic in 1973 and gained an M.Sc. and Ph.D. in Telecommunications Systems from the University of Essex in 1976 and 1979 respectively. He is a senior member of the IEEE, a fellow of the IEE and is currently a visiting professor to Essex University and the Polytechnic of East London, and a visiting fellow to University College, North Wales at Bangor. He joined British Telecom Research Laboratories (BTRL) in 1973 and has worked on a variety of analogue and digital transmission studies. In 1978, he became manager of the long lines division and is currently involved with the development of intensity-modulated and coherent optical systems, photonic amplifiers and wavelength-routed networks for terrestrial and undersea cable applications. He was awarded the Queen's Award for Technology in 1990 for his role as project manager in the production of optical receivers at BTRL for the TAT-8 and PTAT-1 undersea cable systems.

David Heatley joined British Telecom as an apprentice in 1971 and later gained sponsorship to study electrical engineering at university. After graduating from Heriot-Watt University in 1978, he transferred to the Optical Communications Division at BTRL. As the recipient of the Flowers Scholarship, he continued his university studies and in 1981 gained his M.Sc. in Communication Systems from the University of Essex. Upon returning to BTRL, he worked on the development of analogue optical-fibre video systems which utilised advanced intensity modulation and coherent techniques. This work led to him gaining his Ph.D. in Optical Communication Systems from the University of Essex in 1989. At that time, he also became a member of the IEE and a Chartered Engineer. In 1985, he became head of a group responsible for the development of advanced optical receivers for terrestrial and undersea applications. In this capacity, he was a member of the team awarded the Queen's Award for Technology in 1990. He now heads a group responsible for future systems studies.

Corporate Directory Systems

C. AMOS†

A rational approach to the design and implementation of a corporate directory system can reduce costs and improve both corporate image and customer relations, and provides the focus for application and communication systems.

INTRODUCTION

This article examines some of the trends in the growth of internal communications systems within large companies and the corresponding growth and diversity of information required to utilise a range of communication services. A database system is described, based on a corporate model, that rationalises the maintenance and distribution of information that is required for people within a company to communicate effectively.

Such a system has been developed within British Telecom's Directory Products Unit.

The system facilitates the management of, and access to, information about an organisation, such as identifying direct reporting relationships, employees' duties or functions, and how they can be contacted.

The system also supports a range of interfaces to provide for general enquiries, friendly-name-to-address mapping, fast PBX operator directory access, and the generation of reports and printed directories.

The system is designed to cope with organisational change and growth and to provide the directory function as part of an integrated Open Systems Interconnection (OSI) product.

Background

The Directory Products Unit was established in 1988 to develop electronic directory products for internal and external markets. This was in response to the recognition that within many large corporations there is a growing need to capture and rationalise corporate directory information. BT had the skills and expertise to identify and develop a product that could be used within BT and could be marketed externally.

The following year, an agreement was signed with BTUK to implement a corporate directory for use within BT. The Internal Communications Provisioning Authority (ICPA), which was established to provide communications solutions within BT, later took over responsibility for specifying the requirements of the corporate directory system (CDS), which is called *INTER-VIEW.*

The system was launched in May 1990 under the external product name *COHORT 500* and is currently in use at Headquarters and a number of Districts. The system is also used to plan and record information for the major reorganisation of BT under Project Sovereign. Information on the new organisation will be used to update the INTER-VIEW system to provide company-wide directory information when the project is complete in April 1991.

MARKET SITUATION—CORPORATE DIRECTORIES

To operate effectively, an organisation needs information to be able to identify and access individuals within the whole organisation quickly and reliably.

An organisation typically utilises a number of communication services to support both internal and customer contacts; for example, telephony, facsimile, postal and electronic mail.

Access to contact information is required by a range of users; for example, personnel, finance and customer-facing. Individual requirements for information may differ, but access is often made to the same information, albeit by different means and for different reasons:

(*a*) switchboard operators require frequent, fast access to identify contacts using a limited amount of information such as extension number, surname or function;

(*b*) management requires detailed analytical reports on organisational resources and changes;

(*c*) employees require general day-to-day access as part of their normal functions; and

(*d*) functions such as facilities management and resourcing require access to maintain day-to-day changes.

For a large organisation, the interaction between people within an organisation cannot rely on personal or local information and must rely on identifying contacts by reference to a role, secretary, location or other indirect (non-personal) characteristics. It is this transition that introduces reliance on an information base with directory access.

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Generally, companies provide a limited 'information directory' in the form of an internal telephone directory containing a list of employees and job titles and possibly including rooms, roles or services. This information may be presented as an A–Z list of all employees, or an A–Z or grade-ordered list for subdivisions or units within a company.

In practice, this tome cannot be relied upon to provide all the information required and is invariably supplemented by individuals with business cards, card files, scraps of paper and by calling on other individuals or services to satisfy enquiries for directory information.

Directories for other, less common methods of contact are not usually produced and it is left to individual bilateral agreement.

More significantly, this communication infrastructure is subject to constant change owing to reorganisation, relocation, staff and role changes and the introduction of new or additional services. Changes to information are rippled throughout the organisation as updates or replacement copies of paper or electronic directories. This process is usually a compromise between the resources required to maintain it and the value placed on recency of information.

The consequences of current working practices are numerous:

(*a*) The production and distribution of up-to-date printed directories are costly.

(*b*) Directory information is usually out-of-date because of the time taken to capture and distribute change information.

(*c*) The support of multiple services often means that the same information is captured, maintained and distributed on more than one system.

(*d*) Information is not consistently entered or represented.

(*e*) Time and resources are wasted where attempts to make contact use incorrect information.

(*f*) Corporate policies on information standards (corporate terminology for buildings, jobs, units etc.) are difficult to publicise and maintain.

(*g*) The distribution of changes to information is slow to permeate throughout the different information directories that are maintained from corporate to individual level.

(*h*) Unreliable information promotes reliance on different sources such as directory enquiry services or personal records.

To summarise the current situation, a common problem exists that is not satisfactorily addressed by any co-ordinated approach where contact is made by a variety of people, using different references and to common information that is constantly changing.

The Corporate Model

To be able to design a system satisfactorily that holds information about an organisation, the system needs to be modelled on the behaviour of the organisation. As with all information systems, the data maintained is a function of the enquiries that must be answered.

A simple model of an organisation can be built by describing the components and the relationships between them, for example,

Components:

An *organisation* consists of persons, jobs, locations and units.

A *person* has a name and a unique identifier.

A *job* resides in a unit, has a title and description.

A *location* has an address and telephone number.

A *unit* has a head of unit and a function.

Relationships:

A job *is performed by* a person.

A person *directly reports to* a person.

A unit *is contained within* another unit.

The representation of information that is related to real-world objects and modelling basic relationships between them allows enquiry information to be used in a natural way.

Change can then be addressed in terms of how it actually occurs—for example, a person who is promoted and relocated to take up the job of someone that has retired—and can be fully and consistently represented by appropriate changes in the information and relationships for the relevant database elements.

Enquiries can use oblique references that use attributes such as job function, geographical location, relationships and context; for example, Mr. Marriot can be addressed as 'my next door neighbour' (context sensitive), 'Sales Manager' (job title), 'my boss' (reporting relationship) or 'Unit Safety Officer' (responsibility).

RELATED EVOLUTION OF COMMUNICATIONS

The last decade has seen the emergence of services based on the long-term investment in open systems. A significant part of this development has been the recognition and adoption of standards, not only for system-to-system communications, but also to enable communication services to be defined and distributed more efficiently and effectively. Administrative procedures to define universal information (*object identifiers*) and the tools to describe, and therefore disseminate, information (ASN.1) are relatively recent developments[1]. It is interesting to note here that these developments are applicable not just to OSI, but to the communication of understanding in general.

This development is represented in the OSI model (CCITT Recommendation X.200) that covers all aspects of open-system communications. The lower OSI layers are relatively well understood and have provided connectivity while the development of open applications has been more recent—a function of less understanding of needs and less confidence to support truly open marketable applications. As a result, the services and protocols that comply with this model have been implemented from 'the bottom up'. Also, services that already existed on earlier networks could benefit from the connectivity provided by use of the lower layers of open systems while continuing to use proprietary application-level protocols within their own closed user groups.

While voice and data networks and communications systems in general (fax, Telex, teletex) become more capable (larger, faster, cheaper) and applications become available for a wider group of users (E-mail, EFTPOS), there has not been a corresponding progress in the area of naming and addressing.

Communication technologies and standards have specified distinct naming and addressing schemes that meet their individual requirements. As a result, the communications service user is exposed to a plethora of addressing information required to identify the addressee.

The following statements have been made regarding practical numbering schemes[2], which are pertinent to this discussion:

> 'Numbering schemes are an essential part of the infrastructure for providing services over switched telecommunications networks...
>
> ...The numbering schemes were also designed to assist in the selection of the path from the point of origin of the call to its destination. This is the basis for separate numbering plans that exist for telephone, Telex and data networks...
>
> ...(there is a) need for universal numbering arrangements'.

While these requirements are true for designing efficient solutions for technology, numbering schemes do not service application-to-application or inter-personal messaging. Universal numbering arrangements are unattainable ideals that are best addressed by universal access to information; in the same way that the OSI transport service makes communication independent of the underlying network, universal access to directories makes naming and addressing independent of the underlying numbering schemes.

Intercept of Corporate Requirements and Communication Service Evolution

Users clearly need to be offered, directly or indirectly, a service from a set of services that is most appropriate for their communication requirement (meeting their criteria). Ideally, the user's criteria should not be limited by the capabilities of the recipient; the communication service can perform the required negotiation. A common example of this recurs when contact is made by telephone and the line is connected to an automatic answering system; the caller may then reappraise his/her communication requirement and resort to an alternative method such as facsimile or contacting a secretary. This process is reactive when it could be proactive.

Standards have been developed for electronic mail and directory services which establish the long-term solution for global integrated messaging. It is important that systems under development are aligned with this approach to achieve the long-term goal.

However, systems based on these standards still need the support of directory-information management and administration. This is a requirement for all the existing communication services, currently in use, that do not align with recent standards, and will continue to remain a requirement as standards are adopted and continue to evolve to encompass new technologies.

Hence a product can be identified that not only meets specific needs, such as fast call by name and management analysis reports, but also provides the focus for integrated services that are integrated from the point of view of the service user, not the technology.

The following are considered primary issues that need to be addressed now, but with a view to the future:

- data standards (and the applications that promote them) are fundamental in achieving efficient and successful communications,
- the demand to communicate both efficiently (ease of access, cost effective, compatible) and effectively (using the appropriate medium) will continue to exist within competitive business, and
- people will rely on accurate naming and addressing information as communication becomes more sophisticated.

COHORT PRODUCT DESIGN

This section describes the product specification that addresses the requirements identified earlier:

- a system that copes with change,
- a single, centralised source and maintenance of information,
- consistent information maintained for each element,
- support for different types of enquiries,
- access to information for a large number of distributed users,
- control of information (both enquiry and update), and
- improved performance at reduced cost.

The basic architecture of the COHORT 500 product (Figure 1) consists of a centralised database and a number of interfaces that provide enquiry access and data distribution according to the type of user.

Database Function

A centralised database management system provides the basic functions for maintaining data and mechanisms for interrogating, modifying and administering a database that is independent of the data.

A relational database allows data to be structured to support flexible enquiries that rely not only on the values of individual data items but also the relationships between them.

The use of a true relational database allows both direct look up, but supportive browsing (compare with directory enquiries)—I know these bits of information and I need this information. (I can get Mr. Marriot's address because he lives next door to ...).

By imposing rules on the values contained in items within the database, the system can police data standardisation, implement corporate policies and establish consistency. These rules are an additional layer of consistency, that are appropriate to the organisation, on the underlying relational database management system.

ACCESS TO INFORMATION

To meet the requirements that the same information is required by different users, the database is accessed via a number of interfaces:

Interactive Man–Machine Interface Access that is structured to provide helpful ergonomic features.

Message Handling (CCITT Recommendation X.400) Directory use to support electronic mail to perform originator/recipient (O/R) name to O/R address mapping.

Structured Query Language (SQL) Programmatic formal access to the underlying database.

Reports and Directories Programmatic access to commonly required representations of the data (for tabular reports and indexed directories).

Directory Service (CCITT Recommendation X.500) Automated OSI access based on formal protocols (currently under development).

Different types of users are recognised to allow different levels of privileged access. A system administration user is allowed to update information; other users may have their view of the data restricted to organisational subsets of the whole data or only a particular set of attributes.

Distribution of Information

It is a primary requirement of the system that information maintained centrally, as a single copy, should be available to all enquirers.

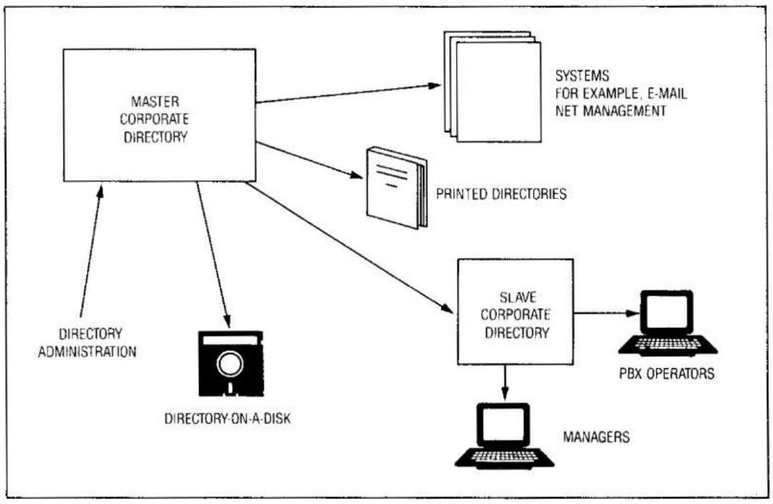

MASTER CORPORATE DIRECTORY
SYSTEMS FOR EXAMPLE, E-MAIL NET MANAGEMENT
PRINTED DIRECTORIES
SLAVE CORPORATE DIRECTORY
DIRECTORY ADMINISTRATION
DIRECTORY-ON-A-DISK
PBX OPERATORS
MANAGERS

Figure 1
COHORT 500 architecture

This is achieved in practice by supporting different distribution mechanisms that allow trade-offs to be made between cost and recency of information:

(*a*) The database may be copied in part or whole to a secondary system to provide local access to directly connected users.

(*b*) Selected database values may be copied to a secondary system that provides faster access to a limited number of values.

(*c*) Access can be by direct interactive terminal.

(*d*) Access can be by remotely connected terminal, over a dedicated or switched network.

(*e*) Selected database values may be presented in the form of a printed directory.

Note that these functions are independent of the database.

PRODUCT DESCRIPTION

General Features

COHORT 500 provides a centralised electronic directory that offers on-line access, update and searching capabilities for casual users and professional users such as operators and receptionists.

Directory users are provided with a range of searching capabilities. Relational enquiries can be used to identify people by their role, skills or responsibilities and to find the right people to deal with queries. Generalised searches may be made on several fields at once and result in the retrieval of a range of data relating to a single entry.

A high-quality printing capability is provided giving users considerable flexibility in the design of content, format and style for printing directory information. A separate PC-based system, called the *Pod* (*P*ers*O*nal *D*irectory), provides specialised access for dedicated use by operators and other demanding users such as receptionists and managers.

An SQL interface is provided for applications to directly access the corporate directory soft-

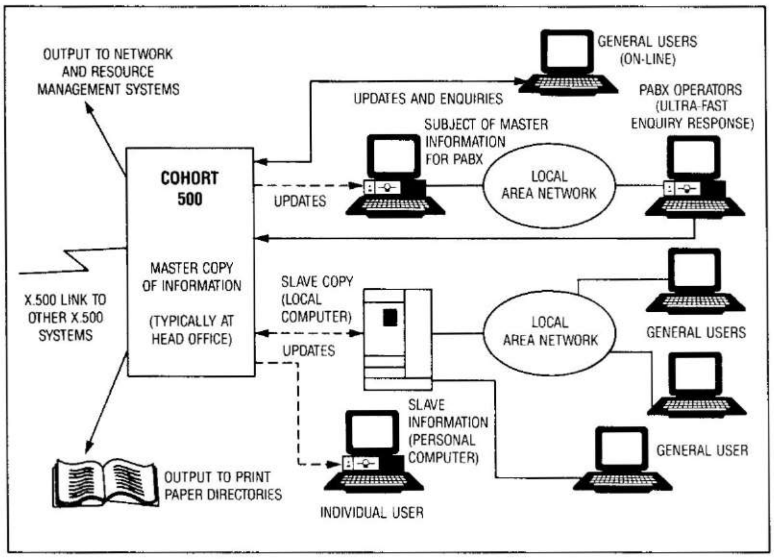

OUTPUT TO NETWORK AND RESOURCE MANAGEMENT SYSTEMS
GENERAL USERS (ON-LINE)
UPDATES AND ENQUIRIES
PABX OPERATORS (ULTRA-FAST ENQUIRY RESPONSE)
SUBJECT OF MASTER INFORMATION FOR PABX
COHORT 500
UPDATES
LOCAL AREA NETWORK
MASTER COPY OF INFORMATION
(TYPICALLY AT HEAD OFFICE)
X.500 LINK TO OTHER X.500 SYSTEMS
SLAVE COPY (LOCAL COMPUTER)
UPDATES
LOCAL AREA NETWORK
GENERAL USERS
SLAVE INFORMATION (PERSONAL COMPUTER)
GENERAL USER
OUTPUT TO PRINT PAPER DIRECTORIES
INDIVIDUAL USER

Figure 2 COHORT 500 typical system schematic

ware and enable non-standard enquiries to be constructed.

The corporate directory system (CDS) conforms to BT's Co-operative Networking Architecture (CNA) and will migrate to the CCITT X.500 Recommendations for directory services.

A typical schematic for a COHORT 500 system is shown in Figure 2.

Directory Enquiry

COHORT supports access to perform enquiries (or updates) from a VT100 or VT200 (or compatible) terminal that may be either directly connected or connected over a network.

Access may be controlled by suitable configuration of the COHORT application and host system to impose user-name and password validation and to specify the initial screen that the user may access.

The user performs an enquiry by being guided through a series of screens which request search information and display the results of the search as a list of entries. The user may select one of the entries listed or progressively refine the search information until the required information has been retrieved. At each stage, the user may elicit screens that provide structured help about the current operation being performed.

The screen layout has features which are common to all screens:

- A title line is displayed consisting of a (configurable) system title, a screen title that uniquely identifies the screen and day and date display. The screen title may also be followed by contextual information about the operation currently being performed.
- A display area contains either an option selection menu, a form consisting of field names and field values that may be optionally entered or modified by the user, or a display of the requested information.
- The description of the functions performed by the eight 'softkey' keyboard function keys PF1 to PF8 is displayed.
- The last line of the screen displays brief messages providing information about the field at the current cursor position, help information, requests for confirmation of current operation and error messages.

Among many features to help the user in making an enquiry, COHORT supports the following:

- One key, normally PF4, allows the user to backtrack to a previous screen. The user may 'unravel' the layers of an enquiry, or may return directly to the initial menu screen.
- Search fields may normally be specified containing 'wildcard' characters, so that the user need only specify the parts of a field that are known and leave the system to identify all entries that match that field.
- A special 'phonetic' search is supported for searching the *surname* field to identify names that have possible alternative spellings, such as Reed, Reid and Read.
- Certain fields are restricted to only containing specific values. These values may be listed and searched to identify the required value to input. The permissible values within these fields are part of the system configuration.

The result of a search is a list of matching entries, at which point the cursor may be positioned to select a single entry.

When a single entry has been identified, the information associated with that entry may be displayed, a screen at a time. For example, the information that the system may store and display for a job entry consists of seven screens of information:

1. Job Details
2. Offices
3. Telephone Numbers
4. Messaging Systems
5. Notes
6. Customer Information
7. Message Handling System Address

A major feature of the COHORT system is that it can display information about the reporting relationships that exist between a person and his/her boss, peers and staff. An organisational tree is drawn on the screen with the selected person at the centre. Above is the person's boss, below are the person's immediate staff, secretary and administration staff. An example of the graphic representation of organisational hierarchy for P. Marriot is shown in Figure 3.

Directory Data

Data is input to the directory, for enquiry or update, by a process of form-filling. However, where data is already held in electronic form or where repetitive changes are being made to entries, facilities are supported for bulk loading of data and specification of global changes.

Each directory entry can be regarded as corresponding to one form, and each item on the form corresponds to one field within the entry. For certain fields, the syntax and data entry are controlled to simplify entry of data and to validate field values.

The organisational structure is represented as a major entity within the database. Whenever a new organisational unit is formed, while updating a job, there is an opportunity to store general information about the new unit such as what it does, who is the boss, general contact information, etc.

Relationships

Additional information is held in the directory and maintained by directory administration to facilitate searching, display and printing requirements.

Within the organisation, and hence the data which describes it, there are many implicit and explicit 1-to-1 and 1-to-many relationships. These are also reflected in the directory and include who works for whom, secretaries, administrators, locations, facilities and services, etc.

Directory Printing and Reports

The COHORT 500 provides a flexible print layout capability to organise and present sets of fields in printed form. Directories are capable of being printed in a variety of layouts and fonts via an output to desktop publishing (DTP).

Three basic types of printed directories are provided by COHORT 500:

Part I An organisationally structured set of jobs and their occupants consisting of selected fields from each entry. This is extracted and sorted using a set of prioritised sort criteria.

Part II An alphabetic listing of surnames together with selected fields such as commonly needed communication and location details.

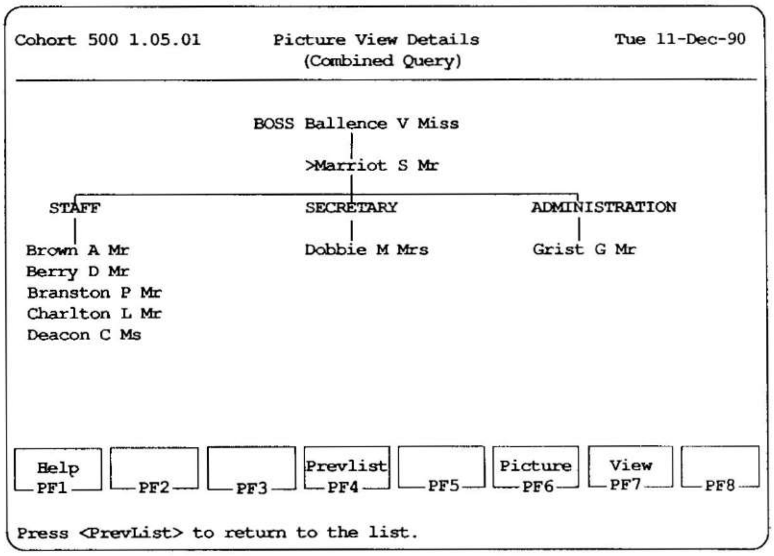
Building Codes A list of building-code abbreviations associated with their full postal address.

The features provided by COHORT that allow selection and ordering of fields in the directory when combined with the features of a DTP system, for editing and merging of material from other sources (such as the company logo), enable a high-quality printed directory to be produced.

Directory Administration

Diagnostic, status and performance information is available to the administrator from the host computer operating system, the relational database management system and from the COHORT 500 application.

Predetermined reports may be requested giving details of the values lists and their contents, user types and the registered users, and fragmentation of the database and available storage space.



Cohort 500 1.05.01 Picture View Details (Combined Query) Tue 11-Dec-90

Press <PrevList> to return to the list.

Figure 3
A picture screen

Distribution

The directory is capable of producing data files, capable of being down-loaded specifically to a slave COHORT 500, COHORT Pod or ISOCOM call logger that is directly or indirectly connected to the directory system.

The process of distribution is automatic, but operates under the control of the directory administrator, who may configure extraction parameters appropriate for each slave system, such as, fields required, data format, frequency of update.

Security

The system conforms to the BT Security Manual, in accordance to the provisions for securing in-confidence data.

The system allows multiple categories of users to be supported and imposes access control appropriate to different types of users to:

(*a*) configure and control the directory system,

(*b*) update directory data,

(*c*) allow enquiry access,

(*d*) generate reports and printed directories, and

(*e*) manage the hardware and directory software.

Data security is supported by maintaining a transaction log such that, in the event of system failure, rollback can be performed to eliminate incomplete transactions; the system may be configured to ensure regular back-up copies of the complete database are made.

Directory Access Products

COHORT PBX Operator's Personal Directory

An important application of an electronic directory is in support of PBX operators receiving calls and enquiries from inside and outside an organisation.

The Pod reflects the customisation of the COHORT 500 to meet a particular business need insofar as it is required to present a suitable selection of fields for fast search by PBX operators.

The overriding factor in the design of the Pod is the achievement of high performance both of machine and operator. To this end, the design minimises keystrokes, hand and eye movements. Word endings are automatically wildcarded. Command inputs are kept to a minimum, with intelligent deduction of the operator's intentions where possible.

The Pod holds a limited subset of data, from the COHORT 500 database, about people, jobs, communications and locations.

There will be occasions when users of this directory will wish to widen a search to obtain a greater functionality. To achieve this, operators using terminals with suitable network connections may, with a single keystroke, connect to a remote COHORT 500 directory system.

The Pod may also be connected to an iSDX console. This allows a telephone number that is found as a result of a search to be dialled automatically. The Pod is also able to determine details of the calling party on incoming calls and to search and display an entry that matches.

Manager's Personal Directory

Many staff use networked terminals and these may be capable of access to the CDS directly. However, many managers and other staff only have access to stand-alone personal computers. In this situation, or where network access is too expensive or too slow, the manager's Pod gives fast access to a recent set of data directly from a PC.

The manager's Pod is supported, by the CDS, by physical delivery (for example, post) on magnetic media of data at periodic intervals.

RESULTS

The COHORT system has been successfully installed on several hardware platforms and implemented in a range of configurations according to customer requirements.

In addition to the features that provide direct benefits, such as the ability to perform phonetic searches and to make relational enquiries, it is believed that a number of indirect benefits are also provided by use of the system:

- better company image,
- better customer service, and
- focal point for corporate communication policy.

The experience that has been gained from a year of experience of line service, together with feedback from customers, has identified areas for future development. These include features to enable customers to enhance forms and fields to their requirements, and the refinement of interactive interfaces to support additional types of enquirers.

The architectural features of a central system with several service interfaces, combined with a powerful relational database, give customers the ability to extend the application of the directory and to integrate the directory with new or existing systems.

CONCLUSIONS

The COHORT product provides a practical solution to corporate directory requirements and the ability to grow and develop to encompass emerging services without the need to re-engineer the system.

Features are provided that allow the customer the flexibility to implement or maintain corporate specific standards, terminology and conventions without undermining the integrity of the system.

The product will be well placed to realise development of corporate networks.

The development in communication technologies, the improved price and performance of computing facilities, the progress of standards work and the increased complexity of business operations have collectively contributed to the need for corporate strategies to control and rationalise their use of business communications. The solution available integrates services and provides a focus that benefits the service user and service provider within a corporation.

ACKNOWLEDGEMENTS

The author would like to thank Steve Brabner for his help and encouragement in writing this article.

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Biography

Chris Amos is Senior Systems Architect in Directory Products Unit, Communications Systems Division. He joined BT in September 1990 from Telematics International where, as a project manager, he worked on network management strategy and network applications. Prior to that, he was a computer officer at Birmingham University where he was responsible for the design and implementation of an X.25 network and network user services. He gained a B.Sc. in Physics at Bristol University and an M.Sc. in Computer Science at Leeds University.

First Operational System X Permanent Building in the UK

J. M. PATTERSON†

This article describes the commissioning of the first operational System X Permanent Building which went into service in Westward District in September 1989.

BACKGROUND

The demand by developers in the South-West for more building land is being met in no small way by public authorities and utilities, including health authorities, seeking to dispose of surplus assets. Within Westward District, BTUK, this has resulted in several large residential and commercial developments coming to fruition in the last few years.

This article is concerned with a novel method of providing telecommunications service to one such development on the outskirts of Exeter in the grounds of the former Exminster Hospital, which occupied a 30 acre prime site adjacent to the M5 motorway. The ongoing development includes the building of 400 houses in the grounds of the former hospital. Substantial new business demand is also expected to materialise once the listed hospital building has been refurbished for commercial and light industrial use.

Telephone service to 'greenfield' developments like Exminster is often required at relatively short notice, and this presents BT with a decision on how best to service this sudden and often speculative demand. One choice is to provide service from one or more of the existing exchanges, albeit with attendant implications for switching and line-plant capacity and the need to provide satisfactory transmission. Alternatively, a temporary System X mobile concentrator may be provided if time-scales do not allow the construction and equipping of a permanent exchange building from the outset.

An additional difficulty with the Exminster development was its location near to the edge of the Kennford TXE2 exchange area. Providing service from Kennford would have had a number of drawbacks. The development would have greatly distorted the connections centre-of-gravity for the Kennford area. More seriously, a new 5 km duct would have been required to Kennford TXE2 exchange, which neither had adequate traffic capacity for the forecast demand nor was able to provide the advanced services (direct dialling in, integrated services digital network, etc.) expected by the new business customers.

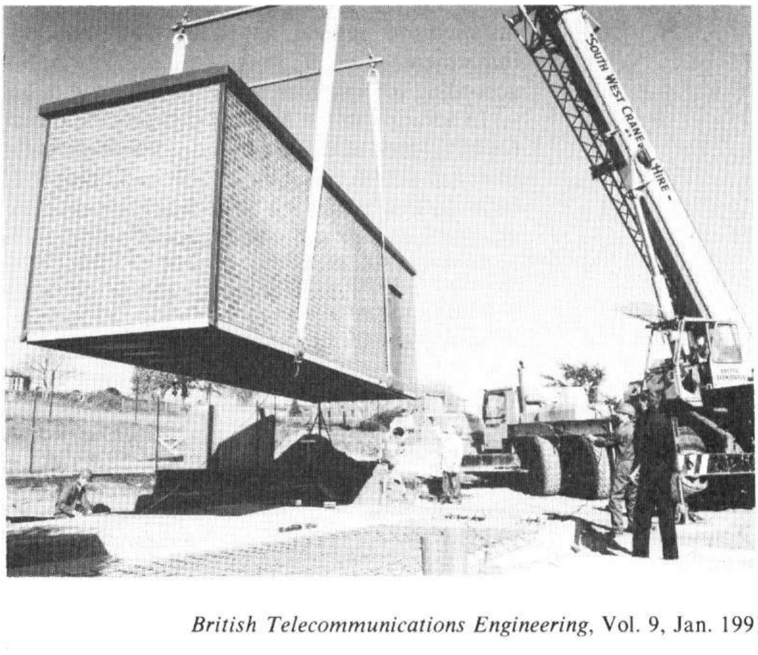
On cost and strategic grounds, it was therefore decided that a remote concentrator unit (RCU) would be needed, saving significant capital investment in the local line sector. As it was clear that a conventional building would not have been ready in time to meet the new demand, a mobile RCU was ordered.

SYSTEM X PERMANENT BUILDING

During the spring of 1989, however, an attractive alternative to the mobile RCU approach emerged with the advent of a new product from GPT, the *System X Permanent Building* (SXPB). The SXPB is essentially a System X RCU housed in a prefabricated building which is clad in imitation brickwork for permanent deployment. It is a development of the standard containerised mobile RCU and is capable of being commissioned within a short time after delivery.

The nature of the proposed development led to the belief that planning permission for the standard mobile would not have been forthcoming for other than a very limited period. Within a very short time, BT would have been forced into committing additional expenditure on a conventional building. The SXPB option, however, was aesthetically acceptable to the local planning authority from the outset. A contract variation was therefore placed with GPT for Exminster SXPB, the first operational SXPB in the UK.

Figure 1
The SXPB being installed on site, on the outskirts of Exeter



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† Westward District, British Telecom UK

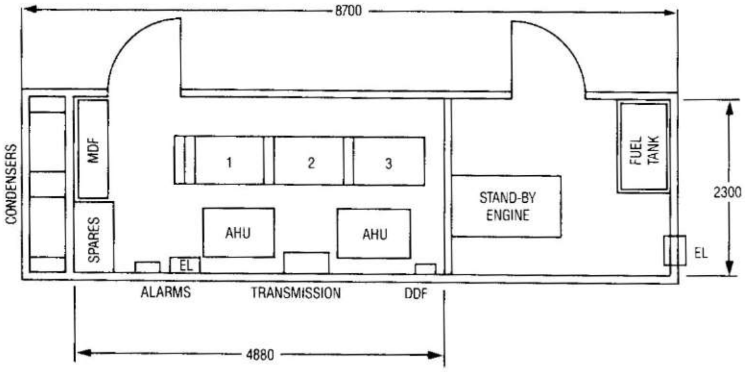
PRODUCT DETAILS

The SXPB contains a standard System X RCU, equipped and tested at the GPT factory in the same way as an ordinary mobile RCU. The steel frame supporting the exchange equipment is clad in a glass-reinforced plastic (GRP) body. The external finish is textured to give a very convincing brickwork appearance. (Several brick colours are available to blend in with local tastes.) Figure 1 shows the SXPB being installed at Exminster.

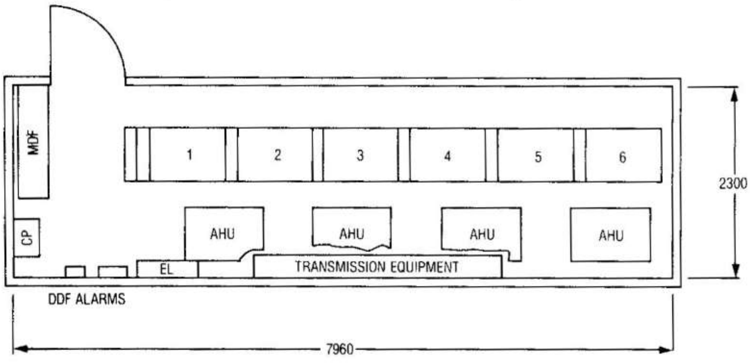
The external dimensions are 3·0 m high, by 2·5 m wide, by 8·7 m long. The interior height is 2·8 m while the equipment area measures 2·3 m by 8·0 m.

FLOOR PLAN AND EQUIPMENT LAYOUT

Figure 2 (*a*) shows the base layout offered by GPT with three System X racks, main distribution frame (MDF) and transmission equipment partitioned off from a smaller room housing the stand-by Compac generator and fuel tank. With the Mk. 1 System X concentrator, this configuration provides a maximum of 960 connections allowing for miscellaneous facilities. (The Mk. 2 System X concentrator can provide a full 2048 connections.) This was not, however, sufficient for the Exminster Hospital development and more System X racks were accommodated by dispensing with the partition and by out-housing the stand-by power equipment. In the actual layout used (see Figure 2(*b*)), the suite of racks was extended to the maximum of six.



(*a*) Standard three-rack SXPB configuration



(*b*) Actual layout used in Exminster SXPB (the condenser units have been omitted for clarity)

AHU: Air handling unit
CP: Cable pressurisation
DDF: Digital distribution frame
EL: Electrical distribution equipment

(All dimensions are in millimetres)

Figure 2—SXPB configurations

The exchange design called for 1216 analogue connections and a bothway analogue calling rate of 0·11 erlangs. The suite comprises three switching racks, two power equipment racks (PERs) and one empty TEP-1H rack for miscellaneous equipment such as Gateway, measurement and analysis centre (MAC), etc. The provision of an unequipped TEP-1H rack for miscellaneous BT use is the practical outcome of a Westward District New Ideas scheme and is now standard Westward practice.

A single-sided modular MDF (Mini Cosmic) is located across one end of the SXPB. The MDF has two line bays with capacity for 2000 line pairs and a single exchange bay serving a maximum of 2560 exchange connections. Cable pressurisation equipment is located alongside the MDF. On the side of the SXPB are a wall-mounted mini digital distribution frame, alarm panel and mains distribution point. Four reduced-height TEP-1E transmission racks are located beneath the air handling units (AHUs).

TRANSMISSION ARRANGEMENTS

The link to the parent processor exchange has been provided initially on radio. All traffic, private and alarm circuits are being fed over a polarised 19 GHz radio link.

A microwave radio dish, mounted 4·5 m high, links the SXPB to the Exeter/Topsham processor 3 km away across the River Exe (Figure 3). By using separate vertical and horizontal polarisations, two 8 Mbit/s systems are provided on the one dish. Exminster SXPB is one of the first exchanges in the country to come into service in this manner.

An optical-fibre feed will be available early this year although the radio system will be retained to provide 50-50 route diversity for the RCU-to-processor link.

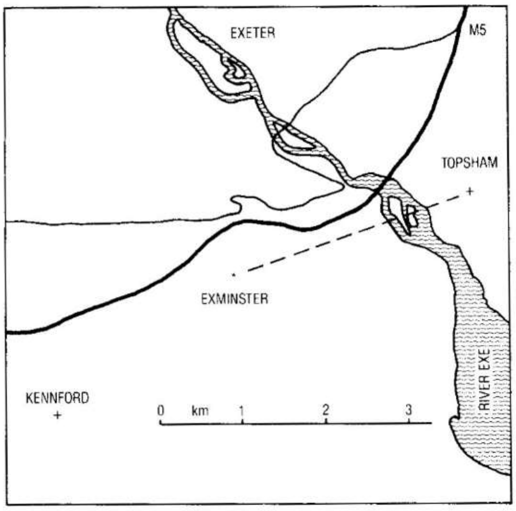


Figure 3—Schematic map showing existing three exchange areas and RCU-to-processor link

AIR-CONDITIONING ARRANGEMENTS

Four ceiling-mounted AHUs recirculate cooled air within the equipment area. The AHUs are provided on the basis of the number required to maintain the normal operating temperature of +24°C, plus one 'hot spare'. Four condenser units, mounted externally on the MDF end of the SXPB, supply the coolant to the AHU evaporator coils.

The cooling arrangements are a major factor in the dimensioning of adequate stand-by power. In the event of the mains supply failing, 2·4 kW is required by each AHU. It is hoped that in-service experience of the thermal performance of the SXPB will allow a reconsideration of the cooling arrangements.

STAND-BY POWER

A 25 kW standard BT power plant housed in a weather-proof glass-reinforced-plastic enclosure is provided for stand-by power. The choice of a 25 kW engine set from the outset will allow for the rapid addition of a second SXPB.

SITE PREPARATION AND DELIVERY

The SXPB is delivered to site on a flat-bed lorry and lifted by crane into position onto a concrete base, pre-prepared with the required duct lead-ins.

POSSIBLE FUTURE APPLICATIONS

The SXPB, in its three-rack configuration, is of a size suitable for UAX13 replacement where this is justified. In practice, however, the lack of space on most Westward District sites would necessitate the purchase of additional land for the SXPB. Additionally, the UAX13 buildings are of limited reuse appeal. A more economic proposition would still seem to be to modernise within the existing building(s), using hot-slide or out-housing techniques as necessary.

A more promising application which will arise in due course is for TXE2 replacement with the advent of the space-reduced Mk. 2 System X concentrator, and the possibility that the SXPB may be made available in other sizes.

The modernisation of TXE2 exchanges within their existing buildings will often release large amounts of redundant floor space. In such cases, it may well be more economic to modernise with an SXPB, particularly where there is scope to dispose of the entire TXE2 building and much of the remaining site.

Despite its status as a permanent building with a quoted design life in excess of 25 years, the SXPB is capable of being relocated. This feature lends itself to situations where growth arising from speculative developments spans several years ahead. This is certainly the case with the Exminster Hospital site and surrounding area. In situations such as this, a mobile may not be acceptable to the local planning authority except for expedient use. On the other hand, the construction of a large conventional building against ill-defined ultimate requirements risks the possibility of an exchange building much larger than ever needed, an outcome not uncommon in earlier modernisation cycles.

CONCLUSION

The SXPB is a valuable product available for deployment by strategic planners for a variety of applications to meet customer demand in an economic fashion.

ACKNOWLEDGEMENTS

Thanks are due to the author's colleagues in Westward District involved in bringing the SXPB into service and for their help in the preparation of this article.

Biography

Jim Patterson joined BT Westward District in 1987 as a direct entrant. He is currently working in the Network Strategy Group with responsibility for long-term planning of exchanges in the Exeter area. He received a B.Sc. in Physics from Edinburgh University in 1983 and a Ph.D. in Atomic Physics from Newcastle University in 1989.

The Modernisation of a Rural Network

K. SUTCLIFFE, A. E. HAYES, and K. NEWBEGIN†

This article describes some of the engineering challenges met during the modernisation of the telecommunications network serving a large rural community in Northumberland. It is based on a lecture given by the authors at the North-East Centre of the Institution of British Telecommunications Engineers.

INTRODUCTION

On the 22 September 1989, the North East District, BTUK, completed one of the most ambitious projects it had ever undertaken—the modernisation of a large rural network in Tynedale, Northumberland, known as the *Hexham cell*. The project, which involved the simultaneous modernisation of 20 analogue exchanges was a District first in many respects. This article describes the engineering challenges which were presented to the planning and works teams, and emphasises some of the novel techniques applied in the modernisation process to overcome difficulties encountered with a rural network and environment.

BACKGROUND

The North East District has two main population centres situated near the coast, Tyneside and Teesside. Beyond these urban/suburban concentrations, there is a very substantial geography of rural England, some 65% of the District's catchment area.

Hexham and the surrounding districts are typical of the North East's rural community. Market towns feature as the focus of community interest; however, business activity is more widespread in that it is primarily based upon agriculture, mingled with some industrial operations and a growing cottage industry. The term *cell* is used to describe a discrete rural community of this type.

Table 1 gives a profile of the Hexham cell before modernisation and compares some of the key elements with North East District totals to give perspective. Again, typical of many rural networks, customers were switched by a small analogue exchange (TXE2 or UAX) towards a small group switching centre (GSC) and tandem unit, situated in this case at Hexham. One important feature to note is the relatively large growth in customer demand for connection to the network which is running well above the District average. There is much activity in business, hotel and private housing development stimulated by Hexham's position which is within easy commuting distance from the business centre of Tyneside.

TABLE 1
Cell Profile
(District figures in brackets)

Customers	16 000 (1 million)
Strowger group switching centres	1
TXE2 exchanges	2
UAX exchanges	17
Area	2000 km^2
Business penetration	23·7% (18·2%)
Growth	7·2% (4·8%)

Why then did the cell approach to modernisation look appealing? It is useful to consider some of the customer, planning and administrative issues which have a bearing on this.

THE RURAL LEGACY

There are several traits which are typical of the switched network serving a rural community:

(*a*) *Complex Routing/Numbering Schemes* It is not uncommon for a mixture of exchange number lengths, local dialling codes and national number group codes to exist in the analogue infrastructure serving a rural community. Dialling practices and procedures are definitely not user friendly.

(*b*) *Low Quality* Although small local exchanges have served the rural customer well for many years, facilities such as automatic routining of exchange equipment, automated performance monitoring etc. are not embedded within the UAX13. Inter-exchange traffic is routed long distances over analogue circuits switched through an analogue tandem exchange. This, combined with the intensive usage of the equipment due to the relatively high calling rates of many of the rural customers, makes it difficult to keep the level of induced noise down to an acceptable level. The Hexham cell exchange fault rate in fact was four times worse than an equivalent urban network.

(*c*) *High Operating Costs* This is inherent with the comparably unreliable analogue equipment and large travelling distances involved. Installation and billing activities are also expensive to run.

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† North East District, British Telecom UK

(*d*) *Volatile Demand* For a variety of reasons—for example, accommodation limitations, number exhaustion, network exhaustion—it can be very difficult to react to demand without a substantial period of notice. Accurate forecasting at the small exchange level is very difficult to achieve, with the impact that expedients have to be employed regularly to meet unexpected demand. It is worthy of note that the revenue from many of the rural exchanges is greater than some suburban equivalents on a per-line basis.

CELLULAR APPROACH TO MODERNISATION

In 1985, the District considered a more radical approach to rural modernisation than had been used in the past—the *cell* approach—that is, coincident modernisation of an exchange network infrastructure. The cellular approach to modernisation offered many attractions:

(*a*) *Potential to Install a Rational Numbering Plan* Considerable simplification of the numbering scheme could be achieved through the creation of an extended linked numbering scheme. This was potentially attractive because of the significant level of community traffic which remains within the boundary of a cell, measured at over 60% in the case of Hexham. More detail of this is given later in the article.

(*b*) *Immediate Service Improvements* Considerable service improvements would be immediately apparent to the customer through the complete removal of analogue switching, both at local and main-network levels.

(*c*) *Cost Reductions* Inherent with the removal of analogue switching was the potential to obtain realisable cost reductions through the modernised geography.

(*d*) *Coherent Network Design* Piecemeal rural modernisation necessitates complex routing strategies in order to imbed a digital unit in a complex analogue network. The cellular approach facilitated the planning for a quality and resilient network solution.

(*e*) *Flexible Capacity* Sub-equipped digital units could be easily extended with the knowledge that there would be no risk that analogue inhibiting factors would prevent unexpected demand being met wherever it may arise.

(*f*) *Rural Commitments* The expectations of the rural customer are steadily rising; comparisons with the high-quality modern digital network are being raised as a political issue.

(*g*) *Commercial and Technological Benefits* It was foreseen that there could have been tangible equipment cost reductions obtained through the innovative use of technology in the rural arena and/or the project could act as a catalyst for manufacturers to offer alternative rural modernisation solutions.

Customers and the District have been able to achieve benefits from all the above facets from the modernisation of the Hexham cell, bar the final one. Current business initiatives may yet achieve this objective.

NETWORK PLANNING

The original concept of modernising the Hexham cell was formulated in 1985. Design work was carried out during 1986, and the project implemented during 1987–89. The network was completed in September 1989.

Three areas of network planning are of particular interest: nodal consolidation, network infrastructure and numbering.

Nodal Consolidation

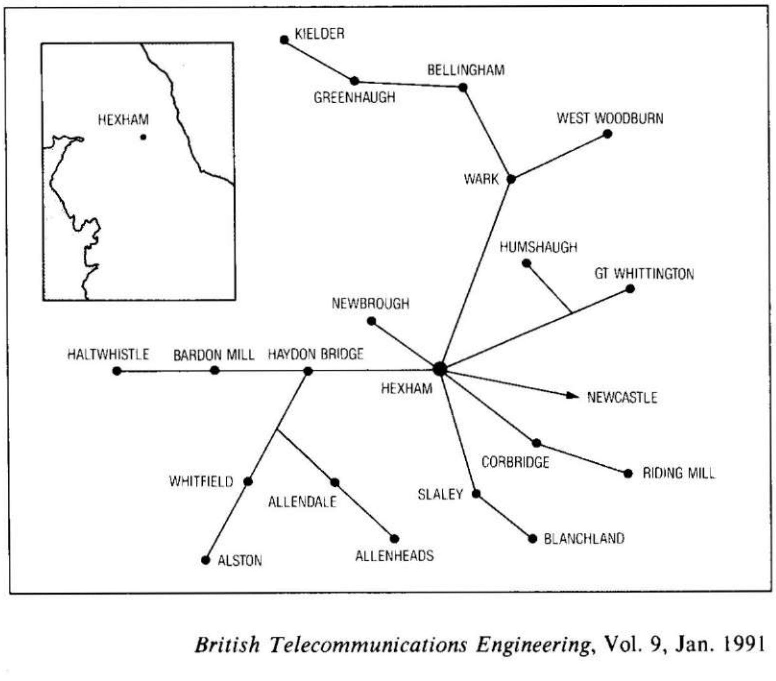
The original nature of the topology of the Hexham group of exchanges is illustrated in Figure 1. As expected with a rural network, the routings focus towards the group switching centre, in this case Hexham. One problem was whether to place a digital processor in Hexham for the 16 000 customers within the cell or to service them from a much larger processor available at Newcastle, some 42 km east of Hexham. In the interests of economy and network development, a decision to use the processor at Newcastle was made, and the exchanges in the group were competitively procured as a single package. System X technology was selected for the cell replacement.

Infrastructure

The network topology designed to serve the Hexham cell network, based upon nodal consolidation, is illustrated in Figure 2. The cable network comprises a mixture of optical fibre, transverse screen and a small amount of digital over copper cables.

The opportunity was taken to obtain the maximum amount of security and resilience compatible with minimum network cost. Hexham, for instance, is connected to Newcastle via two feeds, fibre and transverse screen, routed

Figure 1
Hexham group of exchanges—original analogue network with no diversity



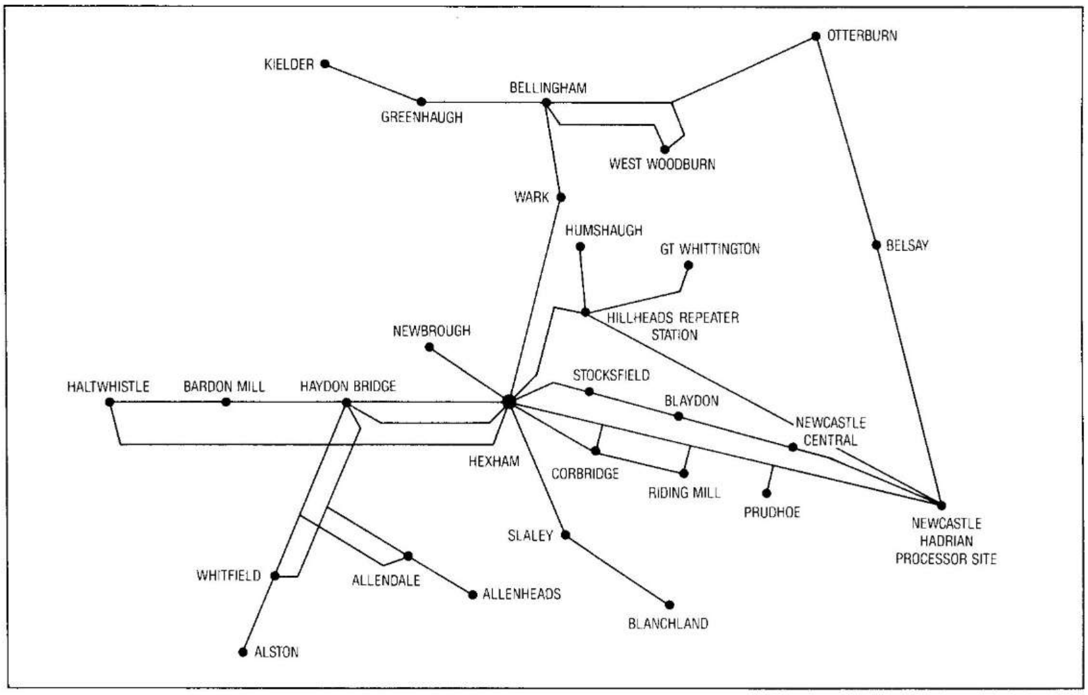


Figure 2 Hexham cell network, Sep. 1989, digital network with diversity

north and south of the River Tyne, on which Hexham is situated.

In total, nine optical-fibre cables (total route length 154 km) were installed in the ground in 38 km of duct. Some novel techniques were used to provide the network at minimum cost. For instance, the digital link between West Woodburn and Bellingham exchanges was provided over two existing 10-pair PET cables split go and return to form an artificial transverse screen cable. Full use was made of the main-network provision, when fibres were obtained from the Otterburn to Newcastle section of a main-network cable.

Other techniques were used to minimise duct costs on specific links. For instance, the route between Slaley and Hexham was congested and the cost of duct relief was forecast to be extremely expensive. A 2-hop 19 GHz radio link was established via the Independent Broadcasting Authority mast at Corbridge to allow copper pairs to be freed and facilitate the provision of a digital route.

The rural terrain presented some unusual challenges. Over 70 bridges and culverts had to be crossed for the provision of the network. One particular bridge could not be crossed and an armoured sub-aqueous cable had to be specifically produced to facilitate a river crossing.

Numbering Considerations

As referred to earlier in the article, the modernisation of the Hexham cell presented the ideal opportunity to rationalise considerably the analogue numbering structure. Figure 3(*a*) shows how the cell was configured before modernisation.

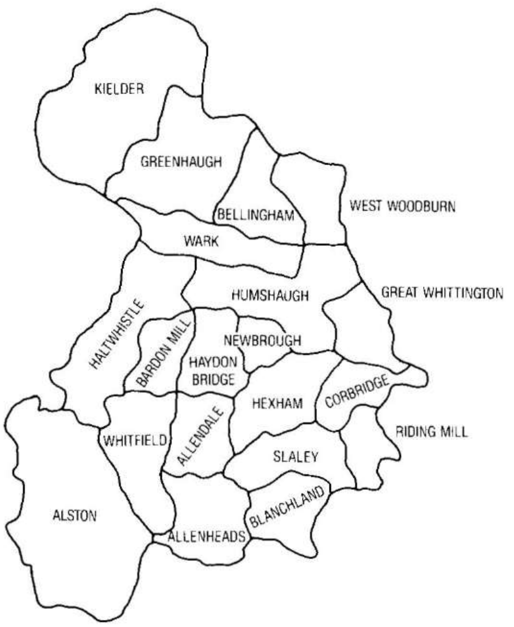
Analogue Numbering Scheme

The cell consists of three distinct charge groups: Hexham, Bellingham and Haltwhistle. Each of these charge groups had a discrete national number group code and the customers within the cell boundary had a variety of number lengths from three to six digits, dependent on exchange type and configuration. Dialling between exchanges within the cell could also be very confusing for customers because of the range and complexity of the large number of local and area codes used. This was complicated by the existence of individual exchange names which required a comprehensive description of dialling procedures and dialling code information within the phonebook.

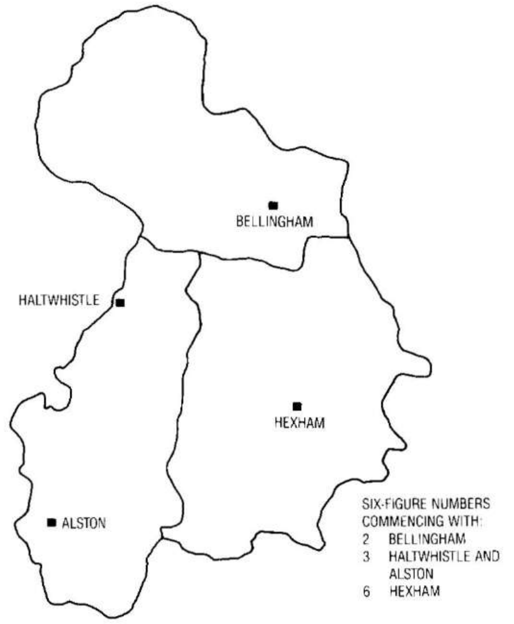
Numbering A Rural Cell in the Digital Environment

The modernisation of the Hexham cell gave the opportunity to take a radical look at the way numbering schemes could be structured. The flexibility of the digital exchange allowed the creation of an extended linked numbering scheme to be considered to serve the rural community as it was believed that this would offer the optimum in numbering simplicity and efficiency in the case of three mutually adjacent charge groups. Figure 3(*b*) illustrates the way in which the routing was designed, each charge group having a discrete lead digit with a common standard number length of six, configured within one national number group (NNG) code. This offered the immediate benefit of the release of two NNGs for reuse nationally.

Once the fundamental routing scheme had been settled, a rationalisation of exchange names could be carried out in order to simplify the dialling procedures. The communities involved



(*a*) Hexham, Bellingham and Haltwhistle charge groups



(*b*) Simplified routing plan

	Local Dialling Codes	Trunk Dialling Codes	Exchange Names
Before Modernisation	29 local codes	15 area codes	16
After Modernisation	0	1 code (0434)	4

Figure 3—Hexham cell numbering modernisation

were consulted, and a decision was made to use generic charge group names for all exchanges contained within the particular charge groups. Alston was the only exception; this name was retained (after local consultation) as its community of interest focussed towards Cumbria to the west. The table in Figure 3 gives an indication of the level of success achieved in simplifying the Hexham dialling codes. Careful publicity ensured that they were introduced smoothly and effectively co-incident with the modernisation of the cell.

INSTALLATION AND COMMISSIONING IN THE HEXHAM CELL

The early project study meetings identified three key requirements to ensure that the Hexham cell strategy would be delivered on time, within budget and with minimum disruption to existing service levels:

- project management,
- minimum rework, and
- a structured method of installation.

Project Management

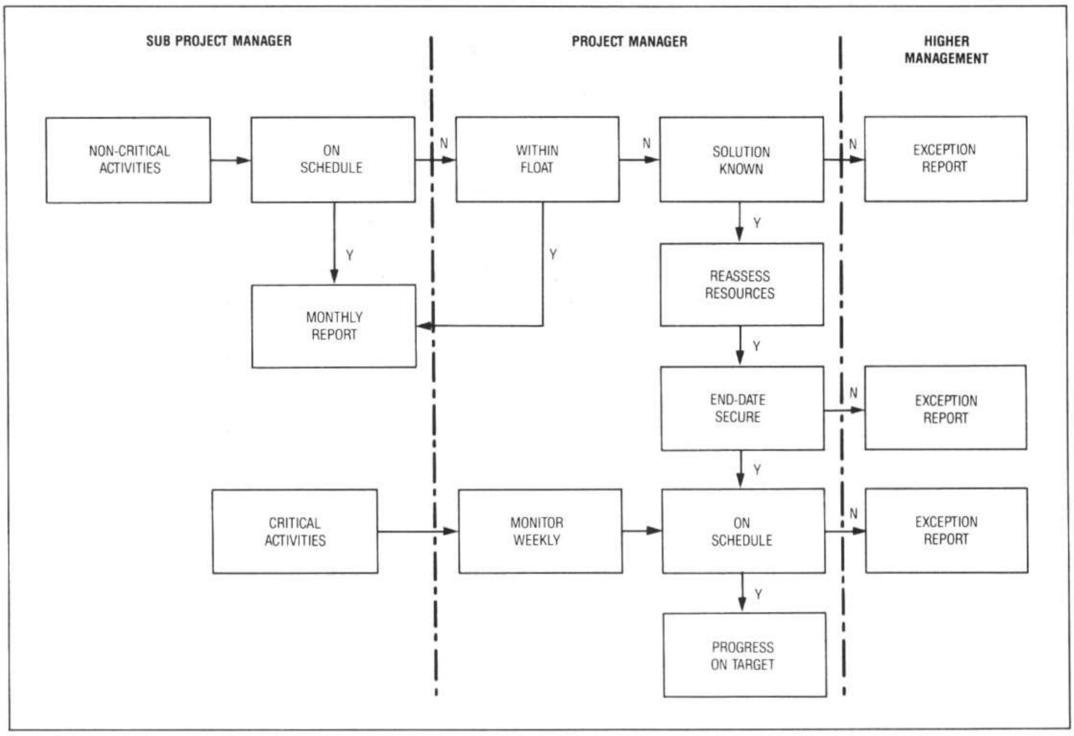
A level 1 manager from the Planning Group was appointed as project manager for the Hexham cell project. The appointment was made from the outset to ensure full end-to-end project management. From detailed activity charts using the Project Management Workbench software, reports were issued showing the progress against high-level milestones and expenditure against budgets. Reporting and escalation procedures are shown in Figure 4. Activities with large amounts of float were monitored on a monthly basis, whereas critical jobs were reviewed weekly. Any exceptions were escalated to senior management to ensure early clearance.

The reporting procedures ensured that each activity manager had full sight of the whole project and therefore visibility of how his activity affected the outcome of each follow-on element. This encouraged full commitment from works and planning managers in the context that they could see where their element contributed to the success of the whole project. Through high-level reports, senior managers also had full visibility of the project at all times. A more detailed report on the project management of the Hexham cell would require an article on its own and as such only a brief overview has been given.

Minimum Rework

To ensure the minimum amount of rework, every endeavour was made to ensure that all equipment racks were installed in their final positions. To enable this, some of the existing exchange equipment was either recovered or repositioned with the agreement of the maintenance staff. The UAX G units, containing the coin-and-fee-check relay-set racks, were made spare by the payphone modernisation and recovered where necessary. These, coupled with the selective replacement of the UAX F units, containing junction relay-sets, which were replaced by pulse-code modulation systems, enabled the new equipment to be installed in its correct position (see Figure 5).

Figure 4
Hexham cell project management



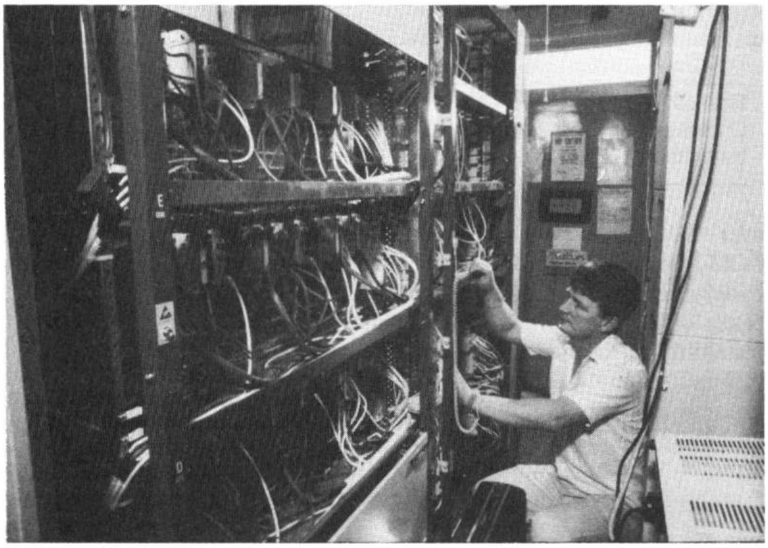


Figure 5
Digital concentrator in UAX building

Minor adjustments were required at four sites, in that the power equipment rack (PER) had to be sited in a separate suite to the remote concentrator (RCC) rack. This occurred because the tender for the project was on the basis that the PER rack would be in line with the RCC rack at all 17 UAX sites. Other UAX racks were moved back, against walls or turned through 90° to enable full installation of the RCCs. However, at two out of the 17 UAXs, progress could not be made without incurring a building extension.

Table 2 shows the extent of the work involved, including the three contract jobs at Haltwhistle, Corbridge and Hexham.

Installation, Commissioning and Bringing into Service

The normal working practice in the District was that a selected team of engineers would install, commission, and bring into service individual RCCs. The number of units involved in the Hexham cell would have required a great deal of fully trained staff and test equipment as some 17 UAXs were scheduled to be installed using direct labour.

One other problem highlighted was the lack of storage space within the Hexham cell and at each UAX site. It was not possible to deliver all the equipment to the UAXs and thus progress the job with all materials to hand. The solution required had to address the problems of staff resources, test equipment and storage space.

It was therefore agreed that the contractor would supply three feeder sites with equipment. The deliveries were phased so that firstly racks, iron work, cables etc. were delivered followed by the shelves and then slide-in units. This was arranged on a site-by-site schedule managed by the project manager.

The methods of working were changed so that installation teams were formed to build and then hand over to commissioning and transfer teams. In all, four installation teams were created with initially one commissioning team which was later backfilled by the installation teams as their levels of work decreased. Towards the end of the project, five commissioning and transfer teams were fully employed within the cell. This resolved the three main problems: the lack of storage space, trained staff and testing equipment.

Frame Installation

Two types of distribution frame—the Frame 7D and COSMIC—were considered for installation at each UAX, the Frame 7D being selected. Both frames are single sided, have insulation displacement terminations and are modular. The main difference between the two frames is that the COSMIC frame has a jumper scheduler associated with its software package for records. Since the frames were small, and there was a limited churn, the jumper scheduler was not seen as a major advantage. However, the local line records database (LLIS/FR) was provided on transfer and this has been used with the OMC facilities to ensure a minimum amount of jumpering activity thus reducing site visits.

The positioning of the Frames 7D was such that access from the existing cable trenches was not possible. A method of accessing the frames and terminating the optical-fibre cable had to be found. It was not considered operationally desirable to extend the existing cable trench bearing in mind the amount of dust that would be generated within the Strowger areas. To enable access to the frame from the external network, a small cabinet was built on the side of each UAX building (Figure 6). This also provided the turning radius required for the termination of the optical-fibre cables (Figure 7). Early installation of the frames enabled both internal and external work to progress in parallel, thus reducing the overall project time.

POWER AND BUILDING ENGINEERING SERVICES

For the Hexham cell project, it was decided that a high level of standardisation in power plant was necessary; therefore the standard System X remote concentrator unit power plant configuration—that is, a power equipment rack (PER) backed up by a stand-by generator (Power Plant 440)—was used. This ensured that the plant design, even in the smallest UAX sites, was consistent with the way the network power and building engineering services will be remotely managed in the future via the Network Administration Implementation Programme (NAIP) philosophy.

The project time-scales and the fact that there were 17 UAX sites did not enable the power equipment to be turned round one site at a time by using mobile plant. The challenge therefore was to provide all the new plant without resorting to building extensions and keep the existing Strowger equipment operating until change-over and its subsequent recovery made space available.

DC Power

All of the existing UAX power plants were of the 227/... series with a battery reserve of 24 hours, which was the largest capacity that could be accommodated in the congested buildings. The larger buildings contained a cross-section of centralised DC plant.

TABLE 2
Hexham Cell Internal Work

	Building Extension	Install New MDF	Recover Relay-Set Racks G and F	Rearrange Equipment	Reconfigure TXD
Allendale		✓	✓	✓	
Allenheads		✓	✓	✓	✓
Alston		✓	✓	✓	
Bardon Mill	✓	✓	✓		
Bellingham		✓		✓	
Blanchland		✓			
Great Whittington		✓	✓		✓
Greenhaugh		✓			
Haydon Bridge		✓	✓		
Humshaugh		✓	✓	✓	
Kielder		✓		✓	
Newbrough		✓			
Riding Mill		✓	✓	✓	
Slaley	✓	✓	✓	✓	✓
Wark		✓	✓		
West Woodburn		✓	✓	✓	✓
Whitfield		✓	✓		
Hexham Corbridge Haltwhistle	Contract Supply and Install				

In all installations, the standard PER (Figure 8) was used in its narrow voltage limit (NVL) format and its capacity was sized to cater for all the ancillary equipment left after change-over to digital; for example, transmission, PCM, private wire circuitry. The minimum battery reserve is normally one hour, but because of the remoteness of many sites and the instability of the mains supplies, the maximum battery capacity was installed in each rack. This gave battery reserve across the sites of between 2–12 hours depending upon individual RCU sizes. One problem was that PERs of the Power System 2020 type are designed for a 3-phase

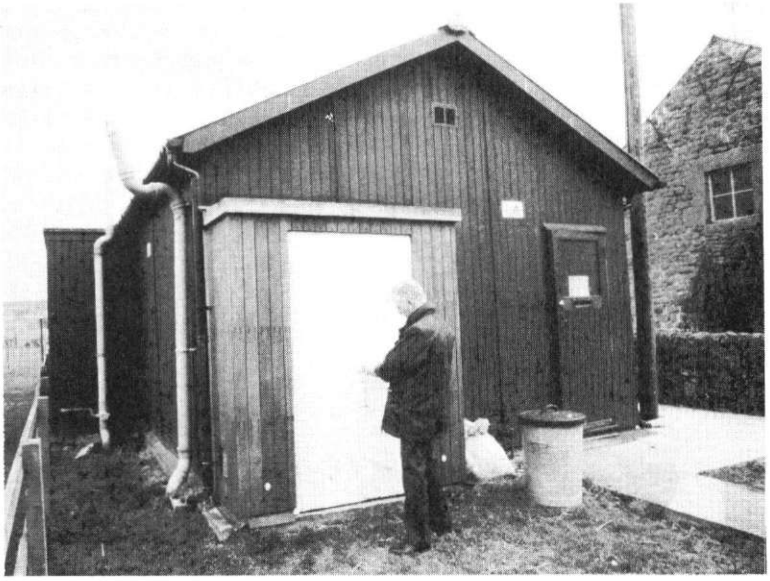
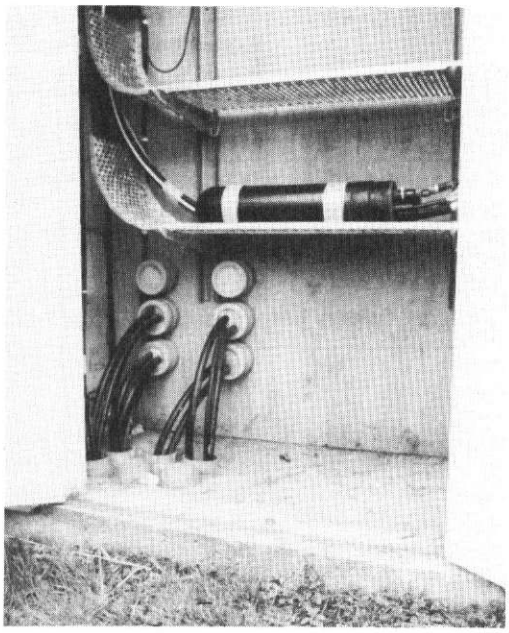


Figure 6
New cabinet constructed at a UAX building to provide access for external network

Figure 7
View inside external cabinet showing arrangement of optical-fibre and copper cables

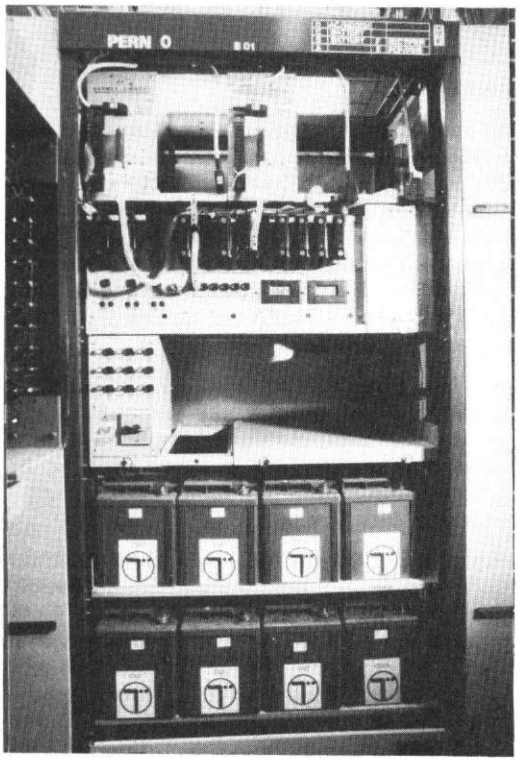


415 V mains input supply; all of the UAX sites were 240 V single phase. Power System 2005 PER, which was designed for the UXD5B and was single phase, was considered, but at the time it was not supplied with the Power Management System 2000 to enable remote management and in some cases did not have sufficient capacity. All the PERs were therefore converted to single-phase 240 V working by rewiring the racks.

AC Stand-by Power

The Power Plant 440 stand-by generator was used for the UAX sites. The sets had to be located outside until the recovery of the Strowger equipment allowed an engine room to be created. The sets were placed, with the aid of a large mobile crane in some cases, on to a temporary engine bed. They were housed in a weatherproof acoustic canopy (Figure 9). To ensure satisfactory operation during winter at these very exposed sites, additional heating was installed around the engine and alternator, together with trace heating to diesel pipes, and lagging around the fuel tank, and the lowest freezing point winter grade fuel was used.

Figure 8
Standard power equipment rack installed in UAX sites to provide up to 12 hours stand-by power



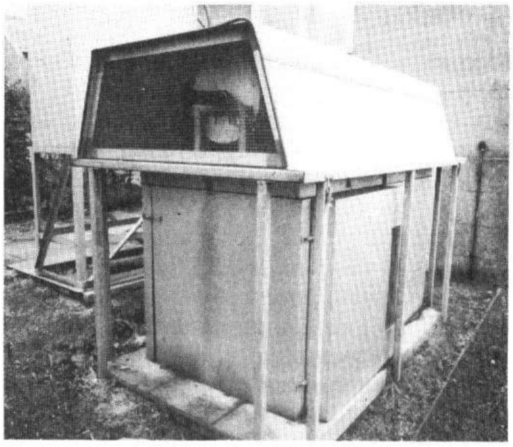


Figure 9—External canopy housing temporary site for engine set

With the exception of one site, the engine control cubicle and associated switchgear were installed in their final position inside each UAX despite the severe space limitations. It was a credit to the BT electricians involved that this was possible. This made the job of installing just the generator in its final position much easier and with minimum disruption to service (Figure 10).

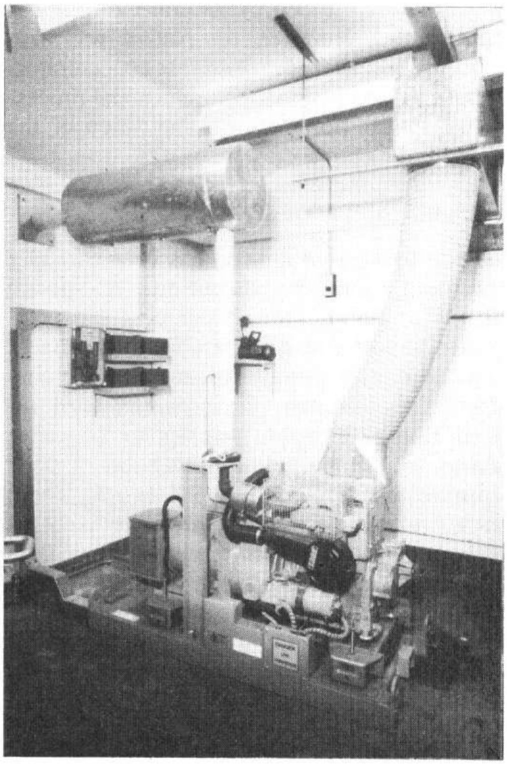


Figure 10—View of engine set in its final location within UAX building

Ventilation

Mechanical ventilation could not be installed at most of the sites until the recovery of the Strowger equipment made space available. Temperature profile calculations using computer modelling techniques demonstrated that it was unlikely the 40°C limit for digital equipment would be approached given normal outside temperatures in this part of the country. However, since the initial design of ventilation for the Hexham cell, design standards have placed a ventilation requirement for all System X installations. This requirment is being met by using the BT Cooling Unit 1A.

General

The remote monitoring facilities and the standby generators were invaluable during the gale force winds in the 1989/90 winter which caused widespread disruption to rural electricity supplies. This was in stark contrast to the problems in maintaining service at non-modernised UAXs using mobile generators transported over large distances, often abortively, because of the lack of detailed plant status information.

TRANSFER

Through project management and the commitment from all those involved, the project progressed on time and within budget towards a transfer date of 22 September 1989. All 20 units were transferred at the same time. Two hours into the transfer, a severe storm, probably one of the worst experienced in Northumberland for some years, hit the area. The storm could be plotted across the cell by its effect on various concentrators. However, the pattern was haphazard. It was later identified that concentrators not affected were connected to the nodal processor by optical fibre, a clear indication of the reliability of optical-fibre networks.

PERFORMANCE OF THE CELL

The performance of the cell has been carefully monitored since its inception. A special TELCARE survey carried out pre- and post-transfer indicated a considerable improvement in the quality of service perceived by the customer. The customer dissatisfaction level reduced from 7% before transfer to 1% after transfer and similarly the perception of poor transmission improved from 9% to 2%. There was a ten-fold improvement in performance as measured by the measurement and analysis centre and a considerable improvement in fault reports was noted across all major categories (Tables 3 and 4).

TABLE 3
Exchange Performance

	Pre-Transfer	Post-Transfer
Customer dissatisfied with last call (TELCARE)	7%	1%
Poor transmission (TELCARE)	9%	2%
Plant defects and engaged (MAC)	2·04%	0·21%
Congestion (weekly overflows)	6553	-
Exchange faults/exchange connection	0·057	0·020

TABLE 4
Hexham Cell—Reports/Faults per Exchange Connection per Annum

	Pre-Transfer	Post-Transfer	% Improved
Total customer fault reports	0·669	0·430	35·7
Network faults	0·250	0·180	28·0
Customer apparatus	0·115	0·082	28·7
Customer fault—right when tested	0·136	0·081	40·4
Customer fault—fault not found	0·025	0·014	44·0
Exchange faults	0·057	0·022	61·4
Underground faults	0·086	0·064	25·6
Overhead faults	0·064	0·055	14·1
Noise reports	0·072	0·049	31·9

CONCLUSION

The successful modernisation of the Hexham cell was due to the enthusiasm and teamwork of the many people involved from its inception to its implementation. The rural network presents many challenges which were overcome through the skill and ingenuity of the teams involved. Tynedale customers now receive a first-class telephone service over a sophisticated network which will give them access to the most advanced facilities available to telecommunications users today.

Biographies

Ken Sutcliffe joined the British Post Office at Leeds in 1968 as an apprentice on exchange maintenance. After being promoted to Assistant Executive Engineer in the North East Region Service Division in Leeds, he moved to Newcastle Telephone Area in 1982 on exchange maintenance duties. He became manager of the North East District Support Group in 1985 and since 1986 has been manager of network planning in the North East District at Newcastle.

Tony Hayes joined the Post Office as an apprentice at Doncaster in 1962. After working on network and switching disciplines, which included works efficiency, medium-term planning and long-term planning, he progressed to his current position of planning and works manager in North East District at Newcastle.

Keith Newbegin began his career as an electrical draughtsman at Swan Hunter shipyards on Tyneside. He joined the Post Office at Newcastle in 1967 as an apprentice on the power group. He progressed to Assistant Executive Engineer on power maintenance and construction, and Executive Engineer on power and building services. He became manager of power and building services in North East District in 1988.

Book Review

Electronics, Computers and Telephone Switching. A book of technological history.
R. J. Chapuis, and A. E. Joel.
Elsevier Science Publishers BV. xvi+428 pp.
US $90·00/Dfl. 175·00.
ISBN 0–444–88042–9.

The last 30 years have seen tremendous changes in telephone exchange switching systems from electro-mechanical technology to the latest electronic digital systems. As this book shows, the transition to today's ubiquitous digital systems was preceded by numerous alternatives, as designers struggled to economically apply technologies which risked being obsolescent almost as soon as the system entered service. Amos Joel, well known for his work at Bell Labs on switching ststems, is well placed to describe the evolution of technology and the effect it has had on the development of telephone exchange and related systems. The authors emphasise the early roots of modern systems, citing among others the work of Boole and Babbage in the last century as well as the more recent work of Reeves, Turing and Flowers. The shared origins of computing and telephone switching control systems are discussed at some length, together with the use of technology common to both applications. The main topic of the book is, however, the evolution of telephone exchange switching systems during an era of rapid technological change when compared to the previous 70 years. This volume charts the worldwide developments that have occurred in electronic space and time division switching systems, the evolution of stored-program control and of common-channel signalling systems. Modern PBXs have a close relationship to modern public exchanges; indeed some modern techniques and technology found their first practical application in PBXs. For this reason, the book includes some of the more important PBX developments.

The development of electronic switching in the UK is well represented, from the early work at Dollis Hill on pulse-amplitude modulation (PAM) under T. H. Flowers, through the reed electronic systems in the TXE series to a quite detailed history and description of the development of System X. The scope of the book outside UK developments is equally impressive; the coverage is worldwide but predominately covers the European, Japanese and the all-important North American (USA and Canada) developments.

It is not a text-book for switching engineers. It should, nonetheless, appeal to them as well as a wider readership interested in the recent history of the subject, as the book aims, with some success, to give a broad perspective on the technical, political, administrative and social aspects surrounding the subject. The authors recognise the defensive nature of most telecommunications markets and self-interest of the source material in much of the period covered. Much of the text is, however, a detached and balanced interpretation of events although, at times, this may be too general and give no more than a pointer to the underlying story. Wherever possible, the book gives pen-pictures or a mention to some of the principal people who have been involved in shaping the current state-of-art in switching. It is a minor blemish on the book, therefore, that in an historical work the identity of the first chairman of the influential CCITT Study Group XI is wrong. From 1960 to 1968, it was Mr. W. J. E. Tobin of the United Kingdom Post Office. Apart from this and a few typographical mistakes, the book appears to be free of errors. This is an important book in the literature on telephone switching systems and deserves to be widely read. It provides access to a wide bibliography on the systems and technology described and can be confidently used as a ready source for reference to a period of immense technological change.

P. B. FRAME

Associate Section Prestige Day

On Friday 19 April 1991, the Associate Section of the IBTE will hold its 18th annual prestige lecture, awards presentation and technical quiz final.

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The programme starts with a lecture at 14.00 hours, usually on a latest development within British Telecom. After a break, the finalists compete for the prestigious Bray trophy, which is presented by the guest of honour. (The guest of honour last year was Dr. David Leakey, Chief Scientist, BT.)

Other presentations are made:

Cotswold Trophy
Best Centre of the year
London Trophy
Best software project
Fudge Trophy
Best hardware project
Anning Award
Young person of the year award

In the evening, there will be a dinner at the Ramada Hotel.

Everybody is welcome; if you would like any further information, then please contact: Howard Duggan, National Quiz Organiser. Tel: Cardiff (0222) 379732.

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